Rules and Efficiency in collective choices : an experimental approach

Vincent Theroude

N° d'ordre NNT : 2019LYSE2043

THESE de DOCTORAT DE L'UNIVERSITÉ DE LYON

Opérée au sein de

L'UNIVERSITÉ LUMIÈRE LYON 2

École Doctorale : ED 486 Sciences Économique et de Gestion

Discipline : Sciences économique

Soutenue publiquement le 24 juin 2019, par :

Vincent THEROUDE

Rules and efficiency in collective choices :

an experimental approach.

Devant le jury composé de :

Marie-Claire VILLEVAL, Directrice de Recherche, C.N.R.S., Présidente

Agnes FESTRE, Professeure des universités, Université de Nice, Rapporteure

Penelope HERNANDEZ, Professeure titulaire, Universidad de Valencia, Rapporteure

Olivier ARMANTIER, Assistant Vice-Président, federal Reserve Bank of New-York, Examinateur

Stéphane ROBIN, Chargé de recherche HDR, C.N.R.S., Directeur de thèse

Adam ZYLBERSZTEJN, Maître de conférences, Université Lumière Lyon 2, Co-Directeur de thèse

Contrat de diffusion

Université de Lyon - Ecole Doctorale de Sciences Economiques et Gestion
Université Lumière Lyon 2

Groupe d'Analyse et de Théorie Economique

Thèse de Doctorat (NR) de Sciences Economiques
Présentée et soutenue publiquement par

Vincent Théroude

le 24 juin 2019

en vue de l'obtention du grade de docteur de l'Université de Lyon
délivrée par l'Université Lumière Lyon 2

Rules and efficiency in collective choices: an experimental approach

---

Directeurs de Thèse :

Stéphane Robin - Chargé de recherche CNRS, Université de Grenoble
Adam Zylbersztejn - Maître de Conférences, Université de Lyon

Jury :

Olivier Armantier - Ph.D., Federal Reserve Bank of New York (US) - Examinateur
Agnès Festré - Professeur, University Nice Sophia Antipolis - Rapportrice
Penelope Hernández - Profesora titular, Universitata de València (Spain) - Rapportrice
Marie Claire Villeval - Directeur de recherche CNRS, Université de Lyon - Examinatrice

Remerciements

Ce travail est l'aboutissement de cinq années qui, malgré des moments difficiles, ont été riches d'apprentissages et de rencontres.

Je tenais à remercier mes deux directeurs de thèse, Adam Zylbersztejn et Stephane Robin, sans qui tout ce travail n'aurait pas existé. Adam, tu m'as appris à être (encore plus ?) exigeant et à dépasser mes propres limites. Tu m'as souvent encouragé à faire fi de ma timidité pour aller vers d'autres chercheurs afin d'améliorer mon travail. Je te remercie pour ta disponibilité, de A à Z (spéciale dédicace). Je te remercie également pour ta patience, parce qu'il en faut pour travailler avec moi.

Stéphane, tu m'as appris à prendre du recul sur mon propre travail. Tu as vu, dès le commencement, ma thèse comme un tout et tes remarques ont toujours été pertinentes pour améliorer la qualité de mon travail. Je te suis reconnaissant de m'avoir toujours soutenu et accompagné sur ce chemin.

Je remercie également Marie Claire Villeval qui a toujours trouvé du temps pour me conseiller. Elle représente pour moi un exemple tant sur le plan de la recherche que sur le plan humain.

A tous les membres de mon jury de thèse, Olivier Armantier, Agnès Festré, Penelope Hernández et Marie Claire Villeval, merci d'avoir accepté d'évaluer mon travail et de m'accorder de votre précieux temps.

Merci au département d'économique de l'université Laval et en particulier à Charles Bellemare, Sabine Kroëger, Bernard Fortin, et Guy Lacroix de m'avoir accueilli. Aux doctorants (devenus docteurs depuis l'heure) : Nicholas James, Steve et Maurice, mes

collègues de bureau durant cette expérience. Ce séjour aura été enrichissant aussi bien sur le plan professionnel que sur le plan humain.
Je souhaiterais également remercier le GATE où j'ai eu le plaisir de faire cette thèse. Merci à Sonia Paty pour ses conseils, sa sympathie et sa disponibilité. Merci également aux enseignants-chercheurs et au personnel administratif pour leur aide précieuse. Un remerciement particulier à Aude et Quentin pour tout le temps et les moyens qu'ils ont consacrés à cette thèse.
A mes vieux briscards et camarades sans qui toutes ces années auraient été moins agréables et certainement moins productives : Rémi, Charlotte, Liza (ma femme de bureau), Yohann, Valentin, Claire, Marius, Jocelyn, Clément, Tidiane, Julien (notamment pour son Tex!), Morgan, Tatiana, Maxime, Thomas, Chrisa, Wilfried, Alice, Benjamin, Tiruo, Chloé, Siwar, Soravich... Merci !
A ceux qui ont participé à cette thèse par leur simple présence : Emile, Barbara et Max, mes amis/amours de toujours (même si un des trois est plus difficile à joindre); pour les instants de détente, Fanny et Camille, nos voisins et amis, partenaires de raclette sans qui les tisanes du soir paraîtraient insipides. Sans vous, on en a gros ! Merci à l'équipe de Curie II (en particulier à Clément et Thomas).
A mes parents et mon frère, pour leur patience et leur soutient, eux qui m'ont toujours encouragé dans mes études, cette thèse est un peu la leur. A ma belle-sœur et mes beaux-parents, pour ces bons moments.
A Jump, Hina (RIP ma belle !) et Zelda, fidèles (?) félins qui m'ont apporté calme et sérénité. A tous merci !
Un merci tout particulier à Amélie, sans toi, tout ceci n'aurait jamais été possible.

Contents

List of Tables

List of Figures

General Introduction

0.1 State of the art

0.1.1 Context

Cooperation - along competition - is a central ingredient in the evolution of certain animal species and human societies. In their book, Aron and Passera (2009) describe the example of lions. Among these animals, nearly 50% of the hunts are collective and food is shared within the herd. Alone, lions are poor hunters - among other reasons because males' fur made them visible and because they have little stamina - but together, they succeed to survive. In the animal kingdom, cooperation between individuals is often exclusive to the same kin and to the same herd. Cooperation between two species is less common (Clutton-Brock, 2009). Being part of a network is a crucial key of cooperation both in the animal kingdom and in human societies. It allows (i) to have repeated interactions with individuals and therefore to build a reputation and (ii) to create social links with other individuals. For these two reasons, individuals may want and have an interest in cooperating with their relatives and with their close friends.

Yet, in some situations, unrelated agents have to cooperate. Hardin (1968) presents in his article the "Tragedy of Commons". This situation happens when agents compete for scarce resources. This competition leads to an over-exploitation of the resources that is detrimental to the whole community. One example lies on fish stocks. Fish stocks are decreasing critically with modern fishing techniques that scale up bycatch, the accidental capture of undesired marine life.[1] The Tragedy of Commons concept has become a central component of the ecological thinking. In order to overcome the Tragedy of Commons, economists have either promoted solutions based on markets (e.g. emissions trading) or based on government intervention (e.g. fishing quotas). Elinor Ostrom has focused her work on how to solve the Tragedy of Commons. In her book, *Governing The Commons*, Ostrom (1990) has offered an alternative solution in which agents "govern themselves" - local communities implement institutions and rules, and succeed to manage their resources (e.g. groundwater, forest) efficiently. Yet, in these situations, agents have no interest to cooperate - by not over-exploiting the resources.

The first mention of the free-rider problem is made by Olson (1965) in *The logic of collective action*. In his book, Olson highlights the fact that, in many situations, individuals' interest overrides collective interest. A rational and self-interested agent should not cooperate - in other words, she should free-ride - in order to maximize her welfare.[2] Yet, if all agents cooperated, social welfare would be maximized. This kind of situation is therefore costly for the society. The author illustrates his idea with the example of trade unions. Every worker benefits from the union, however, contributing - by giving time or money - to the union is costly. As a result, unions have few members and lose bargaining power. The under-representation of workers in trade unions is costly to all workers.

Particular attention has been paid to these situations - called *social dilemmas* (Dawes, 1980). Do agents cooperate? Under what conditions do they cooperate? For what reasons? How to improve cooperation? Social sciences have already given answers to these questions. In this introduction, I will present the main responses found in experimental and behavioural economics.

[1] The standard definition of bycatch concerns caught animals of the wrong species (i.e. untargeted), of the wrong sex, or too young individuals from the targeted species. Using another definition, "bycatch is catch that is either unused or unmanaged", Davies et al. (2009) estimate that bycatch represented 40.4% of global marine catches between 1999 and 2004.

[2] By rational, economists mean that the agent is able to make the choice that maximizes her utility. By self-interested, they mean that the agent is focused only on her own welfare.

0.1.2 Why study cooperation in the laboratory?

The objective of experimental economics is to study the decisions of economic agents (mostly students) in a controlled environment.[3] These environments are designed by the experimenters to answer a research question. The environments designed are simple and most often decontextualized in order to facilitate replications and to gather evidence. Agents' decisions are paid since the seminal work of Smith (1962), in order to reinforce the stakes associated with each decision and thus to avoid the problem of hypothetical bias - the difference between the choice declared by an agent and the choice she makes when she has to make a decision that impacts her.

Noussair (2011) reports that, between 2001 and 2010, 13.1% of the papers published in top journals in experimental economics (leaving aside field experiments and neuroeconomic studies) were about social dilemmas. Controlled experiments provide a testbed to study cooperation varying several aspects of the game. For instance, experimenters can study the effect of repeated interactions: do agents act in the same way when they interact once or when they interact repeatedly with the same group members? They are able to determine the factors of cooperation. For instance, how an agent's beliefs about others' cooperation behaviour correlate with her own cooperation behaviour? They are able to test mechanisms that can lead to an increase in efficiency - i.e. a higher level of cooperation. Are agents able to self govern? Under what conditions?

Additionally, in this environment, the cost of cooperation, the ability and the capacity to cooperate, the productivity of the agents, and the return of cooperation are either controlled or determined by the experimenters. Outside the laboratory, the cost of cooperation may depend on the skills of the agents, agents may organize themselves to cooperate, they may have different means (monetary, time available, network,...), and may benefit differently from cooperation. The laboratory makes it possible to isolate and to manipulate the variable of interest in order to find results, all other things being equal.

[3] Students generally have low income and are more sensitive to the monetary incentives associated with each decision. Concerning the public good game, presented in Section 0.1.3, Belot et al. (2015) find that non-student subjects act similarly than student subjects but are less likely to free-ride.

0.1.3 How to study cooperation in the laboratory?

In the laboratory, one way to study cooperation is to let agents play the linear public good game (also known as the Voluntary Contribution Mechanism). The rules of the game described below are common knowledge - known by every subject at the time of the decision. In this game, N agents are part of a group. Each agent has the opportunity to cooperate - by contributing a share of her endowment (e) to the public good. Each monetary unit contributed to the public good (c) leads to an increase in the payoff (π) of all agents by a value of α monetary units - the Marginal Per Capita Return (MPCR) of the public good that can be interpreted as the return of the public good. Each uncontributed monetary unit is stored in the agent's personal account. Agent i's payoff function can be written as follows:

$$\pi_i = (e - c_i) + \alpha \sum_{k=1}^{N} c_k \tag{1}$$

The game is calibrated to create a social dilemma.[4] An individual's payoff is maximized when she does not contribute to the public good because α <1 - in other words, the return of the public good is lower than the return of the personal account. On the other hand, social welfare is maximized when each individual contributes her whole endowment to the public good - because $N \times \alpha > 1$.

There are variations of this game. The return of the public good can be a decreasing function of individual contributions. In this case, one talks about a *non-linear public good game*. The public good can be provided conditionally to a minimum amount of contributions. If this amount of contributions is not reached, then the money contributed is either returned or lost. In this case, one talks about a *threshold public good game*. In this thesis, I will mainly focus on linear public good games.

[4] In most experiences, decisions about the amount to contribute are made simultaneously and privately. It creates strategic uncertainty: agents ignore the choice made by their counterparts when they make their contribution decision.

0.1.4 Do subjects cooperate?

Any selfish and rational agent should not contribute to the public good in order to maximize her income, regardless of the behaviour of the other group members. A situation in which all agents behave like free-riders - by not contributing to the public good - is therefore the unique Nash equilibrium. The set of strategies applies to a single period game, but it is possible with backward induction to define this set of strategies in a game with a finite number of repetitions. To do this, it is necessary to determine the Nash Equilibrium in the last period and by backward induction to determine the subgame perfect Nash Equilibrium.

Nevertheless, many experiments have shown that subjects contribute to the public good. Ledyard (1995) conducts a literature review on public good games. His pioneering work has highlighted the following results:

1. Agents contribute more than the amount predicted by the Nash Equilibrium when the game is played only once or in the first periods when the game is finitely repeated.

2. Contributions decrease over time when the game is finitely repeated.

3. In the final period, contributions are close to the Nash Equilibrium.

Additionally, in her meta-analysis, Zelmer (2003) finds that several factors affect contributions to the public good. On one hand, a higher return of the public good (i.e. MPCR) or repeated interactions with the same group members (also known as partner matching protocols) lead to higher contributions to the public good. On the other hand, she finds that experienced subjects and groups composed of subjects heterogeneous in endowment are associated with lower contributions to the public good.

How to explain subjects' contribution behaviour? Many behavioural explanations have been mentioned.

0.2 How to explain these standard results?

0.2.1 Other-regarding preferences

For a long time, economists assumed that agents were self-interested. In his article, Becker (1974) relaxes this hypothesis and presents a formalization of the utility function of an altruistic agent within a family. The utility of this agent increases when the welfare - through consumption - of her family members increases. Suppose that agent i considers the welfare of agent j in her utility function, then her utility function (U_i) can be written as follows:

$$U_i = V_i(\pi_i; \pi_j) \tag{2}$$

The V_i function is increasing in π_i, i.e. the agent utility increases when her income increases, but is also increasing in π_j, i.e. the utility of agent i increases when the income of agent j increases. It is then possible to calculate a marginal rate of substitution between the payoff of agent i and the payoff of agent j - the quantity of money that agent i is ready to give up to increase the payoff of agent j by one monetary unit. Under certain conditions, an altruistic agent is therefore willing to contribute to the public good to increase the payoff of the other group members.[5]

Several other-regarding preferences theories have been developed over time. Fehr and Schmidt (1999) present in their article a utility function that describes the preferences of an agent averse to inequalities. According to the authors, agents consider in their utility function not only their payoff but also the difference between their payoff and the payoff of the other members of the group. The utility function can be therefore written as follows:

$$U_i(\pi_i) = \pi_i - \beta_i \max(\pi_i - \pi_j; 0) - \alpha_i \max(\pi_j - \pi_i; 0) \tag{3}$$

[5] Using this utility function, Buckley and Croson (2006) show that agents with a high endowment will contribute more than agents with a low endowment in a public good game when agents within a group are heterogeneous in endowment.

U_i represents the utility function of agent i in the case of a two-player interaction. U_i depends linearly on her payoff (π_i) but also on the difference between her payoff and the payoff of another agent j (π_j). β_i represents the disutility felt by agent i per monetary unit she owns in addition to agent j. α_i represents the disutility felt by agent i per monetary unit she owns in less than agent j.

Fehr and Schmidt (1999) assume that $1 > \beta_i \geq 0$ and $\alpha_i > \beta_i$. $\beta_i \geq 0$ means that economic agents (may) suffer when they are richer than the other group member. However, as $1 > \beta_i$, the model stipulates that no economic agents agree to give up one monetary unit to increase the wealth of the other agent by one monetary unit. The second hypothesis (i.e. $\alpha_i > \beta_i$) can be interpreted as follows. An economic agent prefers to be richer by a monetary unit than another agent rather than poorer by a monetary unit than the latter. Under certain conditions recalled by Fehr and Schmidt (1999), there is a multitude of cooperative equilibria in the Public Good Game.

Bolton and Ockenfels (2000) propose the ERC framework - Equity, Reciprocity and Competition - in which agents may be inequality averse. The model differs slightly from Fehr and Schmidt (1999). In this model, the utility (U_i) function can be written as follows:

$$U_i = V_i\left(\pi_i, \frac{\pi_i}{\Pi}\right) \tag{4}$$

with π_i equals to the payoff of agent i and Π the sum of payoffs within the group. V_i is increasing in π_i, and decreasing when the distance between π_i and $\frac{\pi_i}{\Pi}$ increases. In other words, (i) when the payoff of agent i increases, her utility increases; and (ii) if agent i is inequality averse, when her payoff moves away from the average payoff within the group, her utility decreases. In contrast to Fehr and Schmidt (1999), in this model, agents are no longer more averse to disadvantageous inequalities than to advantageous inequalities.[6]

[6]Using the ERC framework, Fischbacher et al. (2014) show that, among inequality averse agents, agents' best responses are increasing as other group members average contributions increase.

Other-regarding preferences may theoretically explain contributions to the public good.[7] Have experimental economists measured some form of other-regarding preferences in their experiments?

With an empirical approach, Fischbacher and Gachter (2010) classify agents depending on their conditional behaviour. To do this, they elicit the conditional contributions of each subject for every possible average value of other group members contribution. Using these conditional contributions, agents are labelled in one of the four categories: free-rider, conditional cooperator, triangular contributor or "unclassifiable". Thus, a subject whose conditional contributions increase as the average contribution of other group members increases is classified as a conditional cooperator. A subject who never contributes to the public good even when the average contribution of other group members increases is classified as a free-rider. Triangular contributors increase their conditional contributions as other group members average contribution increases till a certain amount, and then decrease their conditional contributions when the other group members average contribution goes beyond this cut-off. Finally, a significant share of agents contribute according to a scheme that is not explained by the typology proposed above and are "unclassifiable". Fischbacher and Gachter (2010) identify in their study 55% of conditional cooperators, 23% of free-riders, 12% of triangular contributors, and 10% of subjects with other conditional contributions patterns. The number of free-riders is relatively low in the population.[8]

This distribution is yet important. It can explain the patterns of cooperation in the public good game highlighted by Ledyard (1995) and described above. In the first period, subjects cooperate. Indeed, as free-riders are not predominant in the population, there is a large share of subjects that contribute. Over time, and as free-riders' behaviour does

[7]Reciprocity is another form of other-regarding preferences that may explain cooperation. Theoretical articles such as Rabin (1993); Charness and Rabin (2002); Dufwenberg and Kirchsteiger (2004); Falk and Fischbacher (2006) assume that, when agents anticipate others' behaviour, or in repeated interactions, some agents will respond to actions considered as altruistic by playing altruistically and will respond selfishly to actions considered as selfish.

[8]Other methods have been developed to classify subjects according to their contributions behaviour. See Kurzban and Houser (2005) and Burlando and Guala (2005).

not change, cooperation decays. Conditional cooperators reduce their contribution to the public good so that in the final period, the public good is no longer provided.

Other-regarding preferences may theoretically and empirically explain contributions to the public good. There are potential cooperation equilibria in the public good game under certain conditions. However, is it the only way to explain contributions to the public good? If not, what share of contributions can be explained by other-regarding preferences?

0.2.2 Other reasons raised to explain the standard results

Confusion

Before thinking about social preferences, economists have long suspected that a non-trivial share of contributions to the public good was due to confusion. Confusion could come from two aspects. In a first case, confusion would be due to methodological errors: for example, instructions would not be clear enough, which would prevent agents from determining the dominant strategy of the public good game. In a second case, confusion would come from the agents: despite clear instructions, it is possible to imagine that agents make errors of reasoning in their decision-making process. Andreoni (1995) shows that confusion does not explain all the results found in the literature. According to him, neutralizing confusion is extremely important. It allows (i) to think about new models of learning, and (ii) it gives a greater value to the experimental results found before his paper. If subjects only contribute by mistake, then it is difficult to learn anything from the literature using the public good game. He distinguishes two reasons that may explain contributions: kindness and confusion. Of the 75% of agents who cooperate, half agents do so because they have not understood the game, while the other half do so for other reasons involving kindness. The downward trend in contributions would be explained by the frustration of the kind agents, which would increase over time as their efforts of kindness would not be rewarded. Houser and Kurzban (2002) have developed an innovative experimental strategy to determine the extent of confusion. In their experience, a subject is assigned with 3 virtual agents (i.e. computers). These virtual agents make random contribution decisions - independent of the subject's contribution choice. This information is common knowledge. Provided that subjects are not altruistic towards the experimenter, they have no reason to contribute to the public good. Houser and Kurzban (2002) finally find the same proportion of contributions due to confusion as Andreoni (1995) - i.e. 50%. For Houser and Kurzban (2002), the decrease in contributions over time can be explained by a greater understanding of the game as periods pass.

Reputation building

Another reason that comes to mind to explain the contributions observed in the public good game is that agents want to build a reputation. Agents contribute in the early periods to encourage long-term contributions. However, cooperation cannot be explained only by reputation building, otherwise there would not be a positive level of contributions (i) when agents play a one-period game, or (ii) when agents play over several periods but each time with different partners (also known as stranger matching protocols) (e.g. Andreoni, 1988).

Warm-glow giving

Economic agents do not always contribute to the public good for pure altruistic reasons. In his article, Andreoni (1990) proposes a model of "impure altruism". According to Andreoni, agents can contribute for different reasons: guilt, sympathy, a desire for social recognition, or the welfare associated with the contribution (also called *warm-glow giving*). Warm-glow giving is different from pure altruism. Indeed, any increase in the welfare of agent *j* leads to an increase in the utility of agent *i* when agent *i* is altruistic, regardless of the origin of the increase. An agent feels a sense of warm-glow giving when she benefits more from an increase in agent *j* welfare when she is at the origin of it.

Palfrey and Prisbrey (1997) have set up an experiment that uses the variation of the return from the public good (i.e. MPCR) to distinguish four reasons for contributing to the public good: (i) altruism, (ii) warm-glow giving, (iii) reputation building and (iv) confusion. Their results indicate that, in a Public Good Game, altruism plays an insignificant role in agents' decision-making in contrast to warm-glow giving and to confusion.

0.3 How to sustain cooperation over time?

Experimental economists have found that (i) the public good is underprovisioned - i.e. is not fully provided - but that (ii) a non trivial share of subjects want to cooperate. The underprovision of the public good is at the origin of a loss in social welfare. Yet, it is possible to rely on cooperators to encourage contributions to the public good over time. In order to improve efficiency in such situations, economists have designed mechanisms. Several types of mechanisms have been implemented (for a review of literature on mechanisms, see Chaudhuri, 2011). Two types of mechanisms can be distinguished: the centralized ones and the decentralized ones. In the former, an institution is generally able to observe the contributions of each agent and act according to a rule publicly known *ex ante*. In the latter, the management of the group depends on its members. Mechanisms used in the laboratory can be classified in three categories: the ones which use monetary incentives, the ones which use image concerns, and the one which use information.

In the first category, good behaviour - beneficial to the community - is rewarded either by peers (e.g. Rand et al., 2009; Sutter et al., 2010) or by a central authority (e.g Dickinson and Isaac, 1998) when bad behaviour is punished (e.g. through taxes (e.g. Falkinger et al., 2000), exclusions (e.g. Croson et al., 2015), or peer punishments (e.g. Ostrom et al., 1992; Fehr and Gachter, 2000)). Take the example of peer punishment. In Fehr and Gachter (2000), subjects play a two-stage game. The rules of the two stages are publicly known before subjects make their decisions. In the first stage, subjects play the standard Public Good Game. In the second stage, they have the opportunity to punish any group member at a cost. Each punishment point leads to a decrease in payoff by 10% of the targeted agent. The game is repeated 10 periods. The authors find that punishment is associated with significantly higher contributions to the public good in both stranger and partner matching protocols. Many authors have manipulated this mechanism to highlight several findings. First, the mechanism is likely to be efficient - in other words, the aggregated cost of punishment is lower than the aggregated benefit due to the increase in contributions - when the VCM is repeated a large number of times. In Gächter et al. (2008), the game is either repeated 10 periods or 50 periods depending on the treatment. The authors find that contributions in the last period are higher (and almost fit the Pareto dominant situation) when the game lasts 50 periods and that the level of punishment is almost 0 in this period. This is not the case when the game lasts only 10 periods. In the same vein, Walker and Halloran (2004) find that punishment does not increase efficiency when VCM is played only once. Second, results depend on the cost-efficiency ratio of the punishment mechanism (Nikiforakis and Normann, 2008). When the cost-efficiency ratio of the mechanism is lower than 1:3 (punishment costs one monetary unit and decreases the payoff of the targeted agent by three monetary units), cooperation is not sustained. The standard decay of contributions happens and the social cost of punishment is larger than the social benefit due to the increase in contributions. Worst, punishment may lead to detrimental effects. Anti-social punishments - punishments against high contributors - are likely to happen when feedback is available (Nikiforakis, 2008).[9] This phenomenon is not rare and may emerge for potential cultural reasons (Herrmann et al., 2008). In the worst-case scenario, punishment can lead to feuds and to a total destruction of the social welfare when the cost of punishment is almost null and when subjects have the possibility to counter-punish (Nikiforakis et al., 2012).

In the second category, agents contribute to preserve a good image. For instance, communication through disapproval points (Masclet et al., 2003) or pictures of the top (or bottom) contributors (e.g. Andreoni and Petrie, 2004; Jacquet et al., 2011; Samek and Sheremeta, 2014) are mechanisms based on self and social image that can lead to an increase in contributions to the public good. In this kind of mechanisms, agents contribute for different reasons: they may contribute to avoid shame or to get honoured

[9] Note that Ertan et al. (2009) propose a solution to tackle this problem.

(Jacquet et al., 2011), or they may contribute to be the "good example", knowing that subjects use social-comparison as a reference point (Andreoni and Petrie, 2004).

Finally, the last kind of mechanisms rely on beliefs, information or feedback. Regarding information, subjects can in some experiments communicate (e.g. Ostrom et al., 1992; Bochet et al., 2006; Bochet and Putterman, 2009). Communication through cheap talk allows subject to coordinate on a strategy and may potentially affect beliefs about other group members average contribution. Communication generally leads to an increase in contributions (e.g. Ostrom et al., 1992; Bochet et al., 2006; Bochet and Putterman, 2009). Regarding beliefs, subjects can have advice given by former participants (e.g. Chaudhuri et al., 2006). In this experiment, the authors argue that the advice transmitted lead to optimistic beliefs about other group members average contribution and to higher contributions. Finally, regarding feedback, in Nikiforakis (2010), subjects in one treatment have a detailed feedback about every group member's earnings. In another treatment, they have a detailed feedback about every group member's contribution. Nikiforakis (2010) finds that subjects tend to be less cooperative when they have information about earnings with respect to the situation in which they have information about contributions.

0.4 Research Question

In the laboratory, cooperation has been carefully studied over the last 40 years. However, experimental economists have to make a trade-off between control and external validity. By maximizing control, they ensure that external factors (e.g. cultural or social influences) do not affect their results. They conduct experiments that are easy to replicate and that allow them to isolate the effects of their treatment through an incentive scheme. By favouring control over external validity, experimental economists choose simple environments that may be unrealistic.

In the case of public goods, they have chosen an environment in which agents are homogeneous in endowment and in which the return on the public good is certain, known in advance by all agents, and homogeneous within a group. Most of the results described in this introduction have been found in this environment. Yet, these assumptions are strong: economic agents do not always know with certainty the return of the public good (e.g. the return of a scientific collaboration), it is likely to vary over the course of a lifetime (e.g. the return of public infrastructures), and both the return of the public good and income are rarely identical between agents in the population (e.g. agents may differ in income or in preferences for public goods). Moreover, uncertainty and heterogeneity (which implies inequalities) are likely to impact contribution behaviours. Agents are, most often, risk averse and are sensible to inequalities. When the return of the public good is risky, or when there is heterogeneity within a group, it may change the contribution behaviour with respect to the standard game. One of the purpose of this thesis is to study cooperation when one or several of the standard hypotheses (i.e. homogeneity and certainty in returns, homogeneity in endowment) are relaxed. Research has already been carried out in this direction and Chapter 1 and Chapter 2 are further steps.

The goal of these two chapters is to see if the standard patterns of cooperation hold in a more complex and more realistic environment. Precisely, in Chapter 1, I investigate the effects of heterogeneity in endowment and heterogeneity in return on contributions in a linear Public Good Game. In Chapter 2 (co-written with Adam Zylbersztejn), we investigate the effects of environmental risk on contributions to the public good. These two chapters offer variations of the standard game that may affect the contribution behaviour of subjects. To predict and explain agents' contribution behaviour, I will apply other-regarding theories to these contexts. What do these theories predict when agents are heterogeneous in endowment or when the return of the public good is risky? Are these models adapted to predict behaviour in a more complex environment? To give an example, in Chapter 2, agents have the opportunity to cooperate in a risky environment. Two theories can be relevant to draw predictions: other-regarding preferences, and risk preferences. No theory mixing risk preferences and other-regarding preferences is unanimously accepted. We have chosen to privilege other-regarding preferences over

risk preferences rather than proposing a new model (which is not the objective of this thesis).
Do theoretical predictions fit with what is observed in the laboratory either by our experiment or by previous studies? In Chapter 1, I survey the literature and summarise the main results found in experimental economics. In Chapter 2, we run a new experiment with a systematic analysis of environmental risk. This experiment allows to gather more data and to enrich the understanding of why and how people contribute to provide public goods.

Chapter 3 is slightly different. The aim of Chapter 3 is to improve public goods provision through a mechanism based on within-group competition. Competition alleviates the tension between individual and collective interest. To test this mechanism, I run an experiment in which agents compete for a better access to the public good (i.e. a higher MPCR). *Ex ante* agents do not know the return of the public good. In this chapter, to give theoretical predictions, I use an extension of the model applied in Chapter 2.

This thesis as a whole offers new insights on cooperation. Understanding cooperation can be useful to the decision maker, especially in resource management issues. Outside the political world, companies often use teamwork for their employees. A better understanding of the determinants of cooperation, finding solutions to tackle the free-riding the problem, and finding an incentive system that promotes full cooperation is likely to interest private companies.

0.5 Overview of the different chapters

0.5.1 Chapter 1

In this chapter, I offer the first survey of the literature focusing on the impacts of agents' heterogeneity in linear public good games. I distinguish two types of heterogeneity: agents either differ in endowment or in the return they obtain from the public good (i.e. MPCR).

Despite excellent literature surveys (for examples, Ledyard, 1995; Chaudhuri, 2011), little attention has been paid to agents' heterogeneity. Yet, agents' heterogeneity is likely to exacerbate the normative conflict inherent to social dilemmas. Normative conflict exists when agents do not share the same view about how to behave. Broadly speaking, agents can be classified in three categories: the ones who favour equality in contributions, the ones who favour equality in payoffs, and those who favour contributions proportional to the return of the public good. Agents who differ in endowment or in MPCR are likely to differ on how they think agents should contribute in a Public Good Game. My starting assumption is that (i) heterogeneity strengthens the normative conflict and (ii) that this normative conflict leads to lower efficiency (i.e. a lower provision of the public good).

Empirical studies - both using lab-in-the-field and natural data - find that heterogeneity or ethnic diversity lead to a lower provision of public goods (e.g. Alesina et al., 1999; Alesina and La Ferrara, 2000; Cardenas, 2003; Miguel, 2004; Miguel and Gugerty, 2005; Algan et al., 2016). However, outside the laboratory, heterogeneity may me multiple and it is complicated to isolate the effects of heterogeneity in income or the effects of heterogeneity in return from the public good *ceteris paribus*. Surveying laboratory experiments allows me (i) to study the effects of heterogeneity found in a controlled environment and (ii) to study if heterogeneous agents are able to use mechanisms to overcome the underprovision of public goods - in other words, if they are able to "govern themselves". For instance, giving them the opportunity to punish may backfire if they do not succeed to agree on a contribution behaviour.

In addition to the normative conflict, heterogeneity is also intertwined with inequalities. Heterogeneity in endowment leads to *ex ante* income inequalities between agents. Heterogeneity in MPCR leads to a situation of efficiency characterized by *ex post* inequalities in payoffs. Using the theoretical framework of Fehr and Schmidt (1999) and of Becker (1974), Buckley and Croson (2006) show that heterogeneity in endowment should trigger larger contributions from high endowed agents while, using the theoretical framework of Bolton and Ockenfels (2000), Fischbacher et al. (2014) show that heterogeneity in MPCR should trigger larger contributions from high MPCR agents.

In fact, agents' heterogeneity does not seem to affect the patterns of cooperation usually observed when agents are homogeneous. Contributions are significant in the first periods but decrease over time and reach a level of almost zero in the last period. Despite a normative conflict exacerbated, in 9 articles out of 12, contributions are not significantly lower in heterogeneous groups than in homogeneous ones. Agents with a high endowment do not contribute more than agents with a low endowment. Agents with a high MPCR contribute more than agents with a low MPCR.

After observing the underprovision of public goods, I study the papers that offer solutions to counter this phenomenon. Punishment is as efficient in groups composed of agents heterogeneous in endowment as it is in groups composed of homogeneous agents. It leads to an improvement in social welfare. The results are more mitigated in a public good game with agents heterogeneous in MPCR. Punishment is less efficient in this context than in homogeneous groups. When agents are heterogeneous in MPCR, punishment often does not improve social welfare. Worst, it can lead to feuds - a total destruction of welfare - when agents have the opportunity to counter-punish. Voting and implementing institutions can improve social welfare when agents are heterogeneous in MPCR but less efficiently than in a homogeneous population. When agents within a group differ in MPCR, the efficiency situation is accompanied by inequalities that are not accepted by all group members. Gangadharan et al. (2017) offer a solution to this problem by giving to the agents the opportunity to communicate and to transfer money once the public good has been provided. Unfortunately, agents heterogeneous in MPCR are unable to coordinate on the usage of this mechanism. They fail to maximize efficiency under the constraint of equal payoffs.

This chapter suggests that heterogeneous agents are able to cooperate. Agents heterogeneous in endowment are even able to govern themselves while there is a need for more research to push agents heterogeneous in MPCR to reach efficiency.

0.5.2 Chapter 2

In this chapter, Adam Zylbersztejn and I are interested in the effects of environmental risk on the level of contributions to the public good. Our baseline is the standard setting in which the personal return from the public good is deterministic, homogeneous, and publicly known. Our experimental treatments alter this classic design by making the marginal per capita return from the public good probabilistic. When agents make their decision, they do not know the value of the return of the public good but they know its distribution. The MPCR can take two values - a high value or a low value - both values being equiprobable. In the Homogeneous Risk Treatment (HomR) the random draw is made for the whole group, while in the heterogeneous risk treatment (HetR) this happens independently for each group member. Each of the treatment consists in two parts. In a first part, subjects play the game only once. Additionally, in this part, we measure beliefs about other group members average contribution and other-regarding preferences (using Fischbacher's method (Fischbacher et al., 2001)). In a second part, the game is repeated for 10 periods with the same group. Subjects do not know that the game would be repeated when they make their decision for the first part.

Theoretically, we know that economic agents incorporate two categories of justice in their decision-making: procedural justice and distributive justice. Procedural justice concerns the opportunity; in other words, the (*ex ante*) expected payoff. Distributive justice concerns the actual payoffs applied *ex post* - after that all agents have made their decision and after that the return of the public good has been determined. In our three treatments, the expected gain is the same. In this way, we eliminate all considerations associated with procedural justice. However, our treatments are such that, for the same set of contributions within a group, payoffs inequalities may be different in the three treatments.

To study agent behaviour, we use the inequality aversion model presented by Bolton and Ockenfels (2000). We simulate the best response function for each treatment for three profiles of agents: agents with a low inequality aversion, agents with a moderate inequality aversion, and agents with a high inequality aversion. These simulations lead us to our research hypothesis: the level of contributions should be higher in HomR than in HetR and the level of contributions in the baseline treatment should be between these two treatments.

Our results do not go in that direction. The level of contributions is the same in all three treatments in the first part. Neither other-regarding preferences nor beliefs about other group members average contribution seem to be different in the three treatments. The correlation between beliefs and contributions is not significantly different in the three treatments. In the second part, the contributions seem to be higher in the HomR treatment. However, this result is explained by the fact that agents contribute more only in the first periods in this treatment. The effect quickly fades away.

These results indicate that the public good game in its standard environment allows for a robust and conservative measure of cooperation. Environmental risk, as long as not competitive (i.e. as long as it does not impose inequalities between agents), does not lead to a decrease in contributions.

0.5.3 Chapter 3

In this chapter, I study the effects of *within-group* competition on public goods provision. Social dilemmas are marked by an asymmetry between individual and collective interests. This conflict of interest leads to an underprovision of public goods and therefore to a situation of inefficiency. The objective of this chapter is to revisit the incentive system in order to align individual and collective interest. To do this, in the mechanism that I implement, there are privileged accesses to the highest contributors. Privileged accesses result in higher MPCRs. Two types of competition with incentives are studied. In the Multiple Prize Rank Order Tournament (MP-ROT), four agents compete for four different MPCRs. In the Single Prize Rank Order Tournament (SP-ROT), four agents are in competition but only the top contributor gets a privileged access. These two treatments make it possible to study the risk/benefit trade-off and to manipulate the potential ex-post inequalities.

These two treatments are compared to a treatment with a tournament without incentives (NP-ROT). In this treatment, agents are ranked according to their contribution but their rank does not give them a privileged access. The agent with the highest contribution is ranked 1 but has the same MPCR as the others. This treatment is close to the standard way to provide public goods. I consider however a tournament in order to control for the non monetary effect of competition - the desire to be ranked first. Does a monetary competition lead to a higher provision of the public good than the standard mechanism? Finally, the two treatments with competition and incentives are also compared to two treatments in which the same MPCRs are randomly assigned (MP-CTL and SP-CTL). The objective is to verify that agents play differently when the MPCR depends on the level of contribution chosen and is not randomly attributed.

From a theoretical point of view, I show that selfish and rational agents are likely to contribute more to the public good when there is competition for privileged accesses (namely in MP-ROT and SP-ROT). To do this, I simulate the average best response function of a self-interested agent for every set of contributions. In both incentivized treatments, the average best response depends on the other group members sum of contributions and on the contribution of each agent. In all other treatments (namely in NP-ROT, MP-CTL and SP-CTL), the best response function is a constant equal to 0. When I look at the best response of an agent who is inequality averse, the predictions are less clear. Indeed, for an agent averse to inequalities, it is costly to behave like a free-rider in a treatment without incentives. Inequality averse agents cannot tolerate being richer than other agents in the group. On the other hand, contributing a large amount in SP-ROT treatment leads to inequalities that are not accepted by agents who are highly inequality averse. Competition with incentives can backfire for inequality averse agents.

Finally, I find that Incentivized Rank Order Tournaments lead to an increase in contributions with respect to NP-ROT. This increase is significant only when there are multiple prizes. Altogether, my results suggest that SP-ROT is less efficient because of the inequalities driven by the treatment. Indeed, the GINI Index is significantly higher in this treatment and, together with my theoretical predictions, it is one way to explain the lower efficiency associated to this treatment with respect to MP-ROT.

Bibliography

Alesina, A., R. Baqir, and W. Easterly (1999). Public goods and ethnic divisions. *The Quarterly Journal of Economics 114*(4), 1243–1284.

Alesina, A. and E. La Ferrara (2000). Participation in heterogeneous communities. *The Quarterly Journal of Economics 115*(3), 847–904.

Algan, Y., C. Hémet, and D. D. Laitin (2016). The social effects of ethnic diversity at the local level: A natural experiment with exogenous residential allocation. *Journal of Political Economy 124*(3), 696–733.

Andreoni, J. (1988). Why free ride?: Strategies and learning in public goods experiments. *Journal of Public Economics 37*(3), 291–304.

Andreoni, J. (1990). Impure altruism and donations to public goods: A theory of warm-glow giving. *The Economic Journal 100*(401), 464–477.

Andreoni, J. (1995). Cooperation in public-goods experiments: kindness or confusion? *The American Economic Review*, 891–904.

Andreoni, J. and R. Petrie (2004). Public goods experiments without confidentiality: a glimpse into fund-raising. *Journal of Public Economics 88*(7-8), 1605–1623.

Aron, S. and L. Passera (2009). *Les sociétés animales: évolution de la coopération et organisation sociale*. De Boeck Supérieur.

Becker, G. S. (1974). A theory of social interactions. *Journal of Political Economy 82*(6), 1063–1093.

Belot, M., R. Duch, and L. Miller (2015). A comprehensive comparison of students and non-students in classic experimental games. *Journal of Economic Behavior & Organization 113*, 26–33.

Bochet, O., T. Page, and L. Putterman (2006). Communication and punishment in voluntary contribution experiments. *Journal of Economic Behavior & Organization 60*(1), 11–26.

Bochet, O. and L. Putterman (2009). Not just babble: Opening the black box of communication in a voluntary contribution experiment. *European Economic Review 53*(3), 309–326.

Bolton, G. E. and A. Ockenfels (2000). ERC: A theory of equity, reciprocity, and competition. *The American Economic Review 90*(1), 166–193.

Buckley, E. and R. Croson (2006). Income and wealth heterogeneity in the voluntary provision of linear public goods. *Journal of Public Economics 90*(4-5), 935–955.

Burlando, R. M. and F. Guala (2005). Heterogeneous agents in public goods experiments. *Experimental Economics 8*(1), 35–54.

Cardenas, J.-C. (2003). Real wealth and experimental cooperation: experiments in the field lab. *Journal of Development Economics 70*(2), 263–289.

Charness, G. and M. Rabin (2002). Understanding social preferences with simple tests. *The Quarterly Journal of Economics 117*(3), 817–869.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: a selective survey of the literature. *Experimental Economics 14*(1), 47–83.

Chaudhuri, A., S. Graziano, and P. Maitra (2006). Social learning and norms in a public goods experiment with inter-generational advice. *The Review of Economic Studies 73*(2), 357–380.

Clutton-Brock, T. (2009). Cooperation between non-kin in animal societies. *Nature 462*(7269), 51.

Croson, R., E. Fatas, T. Neugebauer, and A. J. Morales (2015). Excludability: A laboratory study on forced ranking in team production. *Journal of Economic Behavior & Organization 114*, 13–26.

Davies, R., S. Cripps, A. Nickson, and G. Porter (2009). Defining and estimating global marine fisheries bycatch. *Marine Policy 33*(4), 661–672.

Dawes, R. M. (1980). Social dilemmas. *Annual Review of Psychology 31*(1), 169–193.

Dickinson, D. L. and R. M. Isaac (1998). Absolute and relative rewards for individuals in team production. *Managerial and Decision Economics*, 299–310.

Dufwenberg, M. and G. Kirchsteiger (2004). A theory of sequential reciprocity. *Games and Economic Behavior 47*(2), 268–298.

Ertan, A., T. Page, and L. Putterman (2009). Who to punish? individual decisions and majority rule in mitigating the free rider problem. *European Economic Review 53*(5), 495–511.

Falk, A. and U. Fischbacher (2006). A theory of reciprocity. *Games and Economic Behavior 54*(2), 293–315.

Falkinger, J., E. Fehr, S. Gächter, and R. Winter-Ember (2000). A simple mechanism for the efficient provision of public goods: Experimental evidence. *American Economic Review 90*(1), 247–264.

Fehr, E. and S. Gachter (2000). Cooperation and punishment in public goods experiments. *American Economic Review 90*(4), 980–994.

Fehr, E. and K. M. Schmidt (1999). A theory of fairness, competition, and cooperation. *The Quarterly Journal of Economics 114*(3), 817–868.

Fischbacher, U. and S. Gachter (2010). Social preferences, beliefs, and the dynamics of free riding in public goods experiments. *The American Economic Review 100*(1), 541–56.

Fischbacher, U., S. Gächter, and E. Fehr (2001). Are people conditionally cooperative? evidence from a public goods experiment. *Economics Letters 71*(3), 397–404.

Fischbacher, U., S. Schudy, and S. Teyssier (2014). Heterogeneous reactions to heterogeneity in returns from public goods. *Social Choice and Welfare 43*(1), 195–217.

Gächter, S., E. Renner, and M. Sefton (2008). The long-run benefits of punishment. *Science 322*(5907), 1510–1510.

Gangadharan, L., N. Nikiforakis, and M. C. Villeval (2017). Normative conflict and the limits of self-governance in heterogeneous populations. *European Economic Review 100*, 143–156.

Hardin, G. (1968). The tragedy of the commons. *science 162*(3859), 1243–1248.

Herrmann, B., C. Thöni, and S. Gächter (2008). Antisocial punishment across societies. *Science 319*(5868), 1362–1367.

Houser, D. and R. Kurzban (2002). Revisiting kindness and confusion in public goods experiments. *The American Economic Review 92*(4), 1062–1069.

Jacquet, J., C. Hauert, A. Traulsen, and M. Milinski (2011). Shame and honour drive cooperation. *Biology Letters 7*(6), 899–901.

Kurzban, R. and D. Houser (2005). Experiments investigating cooperative types in humans: A complement to evolutionary theory and simulations. *Proceedings of the National Academy of Sciences 102*(5), 1803–1807.

Ledyard, J. O. (1995). *Public Goods: A Survey of Experimental Research. S. 111–194 in: J. Kagel/A. Roth (Hrsg.), Handbook of Experimental Economics*. Princeton: Princeton University Press.

Masclet, D., C. Noussair, S. Tucker, and M.-C. Villeval (2003). Monetary and nonmonetary punishment in the voluntary contributions mechanism. *American Economic Review 93*(1), 366–380.

Miguel, E. (2004). Tribe or nation? nation building and public goods in Kenya versus Tanzania. *World Politics 56*(3), 327–362.

Miguel, E. and M. K. Gugerty (2005). Ethnic diversity, social sanctions, and public goods in Kenya. *Journal of Public Economics 89*(11-12), 2325–2368.

Nikiforakis, N. (2008). Punishment and counter-punishment in public good games: Can we really govern ourselves? *Journal of Public Economics 92*(1-2), 91–112.

Nikiforakis, N. (2010). Feedback, punishment and cooperation in public good experiments. *Games and Economic Behavior 68*(2), 689–702.

Nikiforakis, N. and H.-T. Normann (2008). A comparative statics analysis of punishment in public-good experiments. *Experimental Economics 11*(4), 358–369.

Nikiforakis, N., C. N. Noussair, and T. Wilkening (2012). Normative conflict and feuds: The limits of self-enforcement. *Journal of Public Economics 96*(9-10), 797–807.

Noussair, C. (2011). Trends in academic publishing in experimental economics. In *Keynote lecture at the Journal of Economic Surveys Online Conference "Communications with Economists: Current and Future Trends" on November*, Volume 16, pp. 2011.

Olson, M. (1965). *Logic of collective action: Public goods and the theory of groups*. Harvard University Press.

Ostrom, E. (1990). *Governing the commons*. Cambridge university press.

Ostrom, E., J. Walker, and R. Gardner (1992). Covenants with and without a sword: Self-governance is possible. *American Political Science Review 86*(2), 404–417.

Palfrey, T. R. and J. E. Prisbrey (1997). Anomalous behavior in public goods experiments: How much and why? *The American Economic Review*, 829–846.

Rabin, M. (1993). Incorporating fairness into game theory and economics. *The American Economic Review*, 1281–1302.

Rand, D. G., A. Dreber, T. Ellingsen, D. Fudenberg, and M. A. Nowak (2009). Positive interactions promote public cooperation. *Science 325*(5945), 1272–1275.

Samek, A. S. and R. M. Sheremeta (2014). Recognizing contributors: an experiment on public goods. *Experimental Economics 17*(4), 673–690.

Smith, V. L. (1962). An experimental study of competitive market behavior. *Journal of Political Economy 70*(2), 111–137.

Sutter, M., S. Haigner, and M. G. Kocher (2010). Choosing the carrot or the stick? endogenous institutional choice in social dilemma situations. *The Review of Economic Studies 77*(4), 1540–1566.

Walker, J. M. and M. A. Halloran (2004). Rewards and sanctions and the provision of public goods in one-shot settings. *Experimental Economics 7*(3), 235–247.

Zelmer, J. (2003). Linear public goods experiments: A meta-analysis. *Experimental Economics 6*(3), 299–310.

Chapter 1

Heterogeneity in Public Good Games: a survey[1]

Social dilemmas emphasize the conflict between individual and community interest common in numerous human interactions. This conflict may lead to inefficiency: a situation in which social welfare is not maximized. In order to study social dilemmas in the laboratory, experimental economists have implemented different games. The public good game (hereafter PGG) has been investigated extensively over the last 40 years.[2] In this game, agents have the possibility either to cooperate - by contributing to a public good - or to free-ride - by keeping their money. Social welfare is maximized when every agent cooperates but each agent's best response is to free-ride.

Ledyard (1995) and Chaudhuri (2011) have written two important surveys for the understanding of the PGG. Ledyard (1995) points out regular patterns of contributions in standard settings. Agents do cooperate more than predicted by the Nash Equilibrium

[1] This chapter is single-authored.

[2] Public good games may take different forms. Linear public good games are defined by a constant Marginal Per Capita Return (MPCR) of the public good - in other words the return from the public good is constant. In non-linear public good games, the MPCR decreases as individual contributions increase. In threshold public good games, public goods are provided if and only if the sum of contributions is above a threshold. If the threshold is not reached, money is either given back to the group members or is lost. In this survey, I will focus on linear public good games such as presented in Section 1.1.1

both in one-shot and in repeated interactions.[3] However, cooperation tends to decay over time when the game is repeated. In the last period, contributions to the public good are close to the best response. These two phenomena are observed both when agents interact with the same group members - in partner matching protocols - or when they interact with different group members over time - in stranger matching protocols. Chaudhuri (2011) focuses on the ways to sustain cooperation and to maximize social welfare (considered as the sum of payoffs within a group in the laboratory) over time. Several mechanisms (e.g. punishment or rewards) lead to high and sustainable contributions over time under certain conditions. For instance, when the cost of punishment is low, Nikiforakis and Normann (2008) show that punishment can improve social welfare. One reason that explains the underprovision of public goods observed in the PGG lies in the heterogeneity in other-regarding preferences within a group. Fischbacher and Gachter (2010) use the Fischbacher method (2001) to classify agents' behaviour. In their experiment, subjects are asked to choose their conditional level of contribution to the public good for every potential other group members' average contribution. Using these conditional contributions, agents are labelled in one of four categories: free-riders, conditional cooperators, triangular contributors or "unclassifiable". Free-riders do not contribute to the public good whatever the level of contribution of the other group members. Conditional cooperators increase their conditional contribution as other group members average contribution increases. Triangular contributors increase their conditional contributions as other group members average contribution increases till a certain amount and then decrease their conditional contributions beyond this cutoff. Conditional contributions that do not respond to these patterns are labelled as "unclassifiable". In their study, Fischbacher and Gachter (2010) find that 55% of subjects are classified as conditional cooperators, 23% as free-riders, 12% as triangular contributors and 10%

[3]Economists have offered several explanations of this phenomenon. Other-regarding preferences theories (e.g. Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) assume that an agent considers the payoff of her counterparts in her utility function. Theories based on reciprocity (e.g. Rabin, 1993; Charness and Rabin, 2002; Falk and Fischbacher, 2006) assume that agents are willing to reciprocate kindly to kind actions. Agents may also experience joy or satisfaction when cooperating (*warm-glow giving* in Andreoni (1995)). Agents may suffer from confusion when making their decisions (Houser and Kurzban, 2002) or make errors in their decision process (Palfrey and Prisbrey, 1997).

are "unclassifiable".[4] This result explains both the non-null contributions observed in the first period and the decay in contributions in the repeated game. A non-marginal share of agents contribute to the public good in the first period. When the game is repeated, and as free-riders keep not contributing, conditional cooperators decrease their contributions.

So far, little attention has been dedicated to a crucial aspect of the game: what happens when heterogeneous (either in endowment or in MPCR) agents play the game? In most experiments, participants playing the PGG have the same endowment and benefit from the same return of the public good. This choice allows experimental economists to maximize control on data, to replicate experiments and to gather evidence. Yet, heterogeneity is likely to strengthen the normative conflict, make coordination harder and therefore to reduce cooperation. Additionally to the standard heterogeneity in other-regarding preferences presented above, subjects now differ in parameters. In the standard public good game with homogeneous agents, equal contributions among group members lead to equal payoffs. When heterogeneous agents - whether in endowment or in MPCR - play the game, this statement is no longer true. Do heterogeneous agents agree on the contribution behaviour the group should adopt? Do subjects manage to provide public goods?

Empirical studies - both using lab-in-the-field and natural data - find that heterogeneity leads to lower provision of public goods (e.g. Alesina et al., 1999; Alesina and La Ferrara, 2000; Cardenas, 2003; Miguel, 2004; Miguel and Gugerty, 2005; Algan et al., 2016). Alesina et al. (1999); Miguel (2004); Miguel and Gugerty (2005); Algan et al. (2016) show that higher ethnic diversity leads to lower spending in public goods. In a lab-in-the-field experiment, Cardenas (2003) shows that participants' wealth and inequalities within a group reduce cooperation. Among the explanations raised, agents may prefer (taste) to interact with people of the same kind - *in group* favouritism (Alesina and La Ferrara, 2000); agents may have lower level of trust when they play with agents different from

[4]See Kurzban and Houser (2005) and Burlando and Guala (2005) for other studies on the same topic.

them (Alesina and La Ferrara, 2002; Cardenas, 2003) or agents may differ in preferences (Alesina et al., 1999).

Outside the laboratory, agents' heterogeneity may be multiple: they may differ simultaneously in culture, in identity, in income and in return from the public good. It is difficult to observe an unbiased causal effect in such a rich environment. Studying the effects of heterogeneity in the laboratory allows experimenters to vary and to control for the nature of heterogeneity. Additionally, they can investigate if standard efficiency-enhancing mechanisms work as efficiently when agents within a group are heterogeneous in endowment/MPCR. Indeed, if agents do not agree on the contribution behaviour that the group members should adopt, giving them the opportunity to punish may not solve the underprovision problem and may even lead to anti-social behaviours - for instance, punishment towards contributors.

Evidence observed in the lab so far seems to indicate a negative effect of heterogeneity on contributions. In his seminal survey, Ledyard (1995) presents six articles with heterogeneous agents (Bagnoli and McKee, 1991; Brookshire et al., 1993; Fisher et al., 1995; Marwell and Ames, 1979, 1980; Rapoport and Suleiman, 1993) and finds a negative effect of heterogeneity on contributions. Yet, he does not distinguish the nature of the environment (matching protocol, information, type of public good) and the type of heterogeneity (endowment in Rapoport and Suleiman (1993), MPCR in Fisher et al. (1995)). Zelmer (2003), 8 years later, reports in her meta-analysis a negative effect of heterogeneity in endowment and no effect of heterogeneity in MPCR on contributions in linear PGGs.

Since the publication of these two works, articles investigating the effects of heterogeneity in PGGs have flourished. This study serves two purposes. First, I survey the post Ledyard articles on the effects of heterogeneity - either in endowment or in MPCR - on public goods provision. This first part allows me to collect and present every result observed and to crosscheck if the effects found in Ledyard (1995) and in Zelmer (2003) hold in the recent literature using linear PGGs. Second, after having observed substantial underprovision of public goods, I survey articles that implement mechanisms to tackle this underprovision.

I find that both kinds of heterogeneity exacerbate the normative conflict. However, most articles on heterogeneity in endowment (5 articles out of 7) and on heterogeneity in MPCR (4 articles out of 5) do not find a significantly lower level of aggregated contributions with respect to the PGG with homogeneous groups. When the game is repeated, contributions tend to decrease over time. At the individual level, subjects with a high endowment generally do not contribute higher amounts than subjects with a low endowment. Subjects with a high MPCR tend to contribute more than subjects with a low MPCR. The normative conflict, caused by the presence of heterogeneity within a group, do not lead to a decrease in efficiency. Introducing mechanisms leads to different effects depending on the heterogeneity type. The good news is that punishment is as efficient in groups with heterogeneity in endowment as in homogeneous ones. The bad news is that mechanisms do not perfectly overcome the underprovision problem in groups with heterogeneity in MPCR. In this situation, the efficiency strategy is associated with inequalities in *ex post* payoffs that are not accepted by low MPCR agents.

1.1 Game and behavioural assumptions

1.1.1 Game

N agents are in a group and have to decide individually and privately which part (c) of their endowment (e) they want to contribute to a public good. Every token contributed to the public good yields α_k token to every agent k in the group ($\forall k \in [|1; N|]$).[5] Every token not contributed to the public good by agent i is kept for her private consumption

[5]There are two main ways to design a public good game. In one case, α_i is considered as the return of agent i from the public good. In this case, each token contributed to the public good - whoever the agent that contributes - yields α_i token to agent i. In the second case, α_i represents the productivity of agent i to the public good. In this case, each token contributed to the public good by agent i increases the payoff of every agent in the group by α_i token. In this case, the payoff function can be written as follows: $\pi_i(c_i) = \beta_i(e_i - c_i) + \sum_{k=1}^{N} \alpha_k c_k$. In a homogeneous linear PGG, both cases are equivalent.

and increases her payoff by β_i token. Contribution decisions are made simultaneously and privately. The payoff function of agent i (π_i) in a period is computed as follows:

$$\pi_i(c_i) = \beta_i(e_i - c_i) + \alpha_i \sum_{k=1}^{N} c_k \tag{1.1}$$

In this survey, I focus on games in which agents within a group are heterogeneous in parameters. Two forms of heterogeneity are of special interest. Agents may differ in endowment (i.e. agents with different e within a group), or in MPCR (i.e. agents with different α within a group).

1.1.2 Heterogeneity and other-regarding preferences

In a linear public good game, the return of the private account, is, most times, higher than the return of the public good (mathematically, $\alpha_i < \beta_i$), such as contributing to the public good is costly ($\forall c_i \in [|0; e_i|]$, $\frac{\partial \pi_i}{\partial c_i} < 0$).[6] A rational and self-interested agent should not contribute to the public good. Consequently, the Nash equilibrium corresponds to a situation in which no agents contribute to the public good. On contrary, social welfare is maximized when every agent contributes her whole endowment. It is a consequence of the calibration: $\sum_{k=1}^{N} \alpha_k > 1$.

Yet, one knows that subjects do contribute to the public good. Fehr and Schmidt (1999) consider that it is possible to explain past results observed in PGGs (among other games) with agents' inequality aversion. According to them, agents' utility depends not only on their absolute payoff but also on the difference in absolute payoffs between group members. The utility function suggested by Fehr and Schmidt (1999) can be written as follows:

$$U_i(\pi_i) = \pi_i - b_i \max(\pi_i - \pi_j; 0) - a_i \max(\pi_j - \pi_i; 0) \tag{1.2}$$

[6] In some case, the MPCR of an agent may be smaller than 0. In this kind of situations, the public good can be seen as a "Not in my backyard" case. The standard example is the construction of an airport which increases the welfare of most inhabitants but which is poorly accepted by people who live close. See Dekel et al. (2017) for a recent paper on this topic.

with $0 < b_i < a_i$. b_i represents, for agent i, the loss in utility due to advantageous inequality while a_i represents her loss in utility due to disadvantageous inequality. An agent prefers to be one dollar richer than one dollar poorer relatively to another agent. Under certain conditions detailed in their seminal paper, Fehr and Schmidt (1999) show that there exist potential cooperation equilibria in a homogeneous environment. What happens when a group is composed of agents heterogeneous either in endowment or in MPCR? Some articles dealing with heterogeneity (e.g. Buckley and Croson, 2006; Fischbacher et al., 2014; Kube et al., 2015) have chosen to incorporate their work in Fehr and Schmidt (1999) framework.

Whatever the kind of heterogeneity, agents with a high type (i.e. a high MPCR or a high endowment) should contribute a bigger share of their endowment and consequently a bigger amount than agents with a low type to decrease inequalities within the group (see the version of the proofs I propose in Appendix A.1). Consequently, if one considers Fehr and Schmidt utility function in a context with heterogeneity in endowment/MPCR, inequality averse agents with a high type should contribute a bigger share of their endowment in order to maximize their utility.[7]

Hypothesis about individual contribution behaviour - Inequality aversion: Agents with a high type should contribute a bigger share of their endowment than agents with a low type, and consequently a bigger amount.

1.1.3 Normative Conflict

Another aspect exacerbated by heterogeneity, and studied for instance by Nikiforakis et al. (2012), Reuben and Riedl (2013), or by Gangadharan et al. (2017), lies in normative conflict.[8] A social norm is defined as a behavioural rule that must fulfil several conditions.

[7] A proof in the case of heterogeneity in endowment is available in Buckley and Croson (2006). Simulations of an agent's best responses using Fehr and Schmidt utility function in the case of heterogeneity in MPCR are available in Fischbacher et al. (2014).

[8] Also studied by Kingsley (2016) in a non-linear PGG, by Brick et al. (2016) in a game when agents differ in abatement costs (i.e. when both α and β are different within a group) and discussed in Kachelmeier and Shehata (1997) with natural social norms that differ depending on the culture of the agent.

A social norm exists when a sufficiently large number of agents know the rule, approve it and are ready to conform to the norm *under the conditions* that others (i) do follow the rule and (ii) expect other group members to follow the rule. Otherwise, it may exist when enough agents are ready to sacrifice a part of their payoff (for example, by punishing) to enforce the application of this rule. A social norm depends on the beliefs about what others consider as a "fair" behaviour and on the beliefs about the applicability of this rule of behaviour. In the literature about heterogeneity in PGGs, economists often mention normative conflict because subjects within a group share different views about the norm of contribution that must be followed. There are in general three different norms that summarize subjects' view: equality of payoffs, equality of contributions, and contributions proportional to productivity/return. In a standard and homogeneous PGG, these three norms are equivalent. In the heterogeneous case, equal contributions do not lead to payoffs equality (neither when agents differ in endowment nor when they differ in MPCR). Consequently, there may be a normative conflict between agents in favour of equality of contributions within a group (input) and agents in favour of equality of payoffs (output). The social norm based on "fairness" is often self-serving. Agents with a low type (low MPCR or low endowment) find "fair" that agents with a high type contribute more than them. Agents with a high type find "fair" that every agent equally contributes to the public good. Both of them want to maximize their own payoff.

1.2 Effects of heterogeneity on cooperation

In this part, the objective is to study the effects of heterogeneity in a PGG when no mechanism is implemented to enhance cooperation. The aim of this part is (i) to see if heterogeneity leads to a normative conflict and (ii) to make an inventory of the results already observed. Results will be separated in two sections depending on the type of heterogeneity.

1.2.1 Heterogeneity in endowment

Observation 0: Heterogeneity in endowment strengthens the normative conflict.

Reuben and Riedl (2013) focus their work on normative conflict. To elicit norms, they examine the online answers of "third parties" who do not play the game. Having at their disposal the instructions, third parties are asked to answer the question "what is the fair amount that each of the group members should contribute to the group project?" and to choose contributions conditional to certain situations. The authors show that third parties do not agree on the contribution behaviours that agents should adopt when they differ in endowment. 12% of third parties favour equality of contributions, 36% of them favour contributions proportional to endowment (different from the efficient strategy), 26% of them favour equality of earnings, 2% of them favour efficiency and 24% of them favour another contribution behaviour. When third parties are asked to choose what kind of contribution behaviour is fair when agents within a group are homogeneous in endowment, 74% of them favour equality of contributions (different from the efficient strategy), 13% of them favour efficiency and 13% of them favour other contribution behaviours. As expected, heterogeneity strengthens the normative conflict. Does this normative conflict reduce cooperation?

Observation 1: 5 articles out of 7 do not find lower aggregated contributions (and therefore lower efficiency) when agents within a group are heterogeneous in endowment.

Two strategies have been deployed to study the effects of heterogeneity in endowment on aggregated contributions.[9] One way to do this (e.g. Cherry et al., 2005; Prediger, 2011; Heap et al., 2016) is to compare agents with the same endowment in two different environments: a homogeneous one and a heterogeneous one. One advantage of this method is that there is no individual wealth effect when comparing individual contribution across environments. Consequently, it is possible to isolate the pure effect of heterogeneity in endowment on contributions. This method leads to mixed evidence.

[9]The calibration and the principal results of every cited article in this section are presented in Figure 1.1.

On one hand, Cherry et al. (2005) and Heap et al. (2016) find that aggregated contributions are significantly lower when agents within a group differ in endowment. On the other hand, Georgantzis and Proestakis (2011) find a positive effect of heterogeneity on aggregated contributions. One aspect of this method is that the aggregated levels of wealth - the sum of endowments before contribution decisions - differ across treatments. Beliefs about other group members' average contribution may be affected by this change. On one side, in a heterogeneous group, an agent with a low endowment is matched with agents with a higher endowment. Consequently, she may expect high contributions from her counterparts, and contributes a high amount. On the other side, in a heterogeneous group, an agent with a high endowment is matched with agents with a lower endowment. Consequently, she may expect low contributions from her counterparts, and contributes a low amount. Cherry et al. (2005) and Heap et al. (2016) show that the agents with the higher endowment contribute more in a homogeneous environment than in a heterogeneous one while the other agents do not contribute differently in the two environments.

Another way to study the effects of heterogeneity in endowment on aggregated contributions is to compare two groups with the same aggregated wealth. Agents in these groups are not endowed with the same amount. Using this method Hofmeyr et al. (2007), find no effects of heterogeneity in endowment on aggregated contributions. The same result is observed in Keser et al. (2013) in a treatment with low inequalities.[10] In two field experiments taking place in Africa, Prediger (2011) and Burns and Visser (2006) find a positive and significant effect of heterogeneity in endowment on aggregated contributions.

Observation 2: Contributions tend to decrease over time when agents are heterogeneous in endowment.

[10]These results are in line with what theory predicts. Warr (1983) and Bergstrom et al. (1986) have respectively developed and generalized the theorem of neutrality that states that a redistribution of income within a society does not lead to a decrease in the provision of public goods as long as the set of contributors does not change.

Burns and Visser (2006); Buckley and Croson (2006); Heap et al. (2016); Keser et al. (2013); Reuben and Riedl (2013) find a negative and significant effect of time on contributions in the treatment with heterogeneity in endowment. Hofmeyr et al. (2007) and Prediger (2011) find no effect of time neither in the homogeneous baseline treatment, nor in the treatment with heterogeneity in endowment. As these two articles also find no effect of time in the homogeneous treatment - which is not common -, such a null effect result may be due to the pool of subjects.

Observation 3: In most articles (5 out of 7), agents with a high endowment do not contribute larger amounts than agents with a low endowment.

Building their experiment on Fehr and Schmidt (1999) inequality aversion theory and Becker (1974) altruism theory, Buckley and Croson (2006) find that, in contrast to what both theories predict, agents with a high endowment do not contribute significantly more than agents with a low endowment. This result has been replicated in several experiments (*e.g* Reuben and Riedl, 2013; Keser et al., 2013; Georgantzis and Proestakis, 2011). Consequently, agents with a high endowment do not contribute a higher share of their endowment. Prediger (2011) even finds that agents with a low endowment contribute a higher share of their endowment to the public good. Two exceptions are found by Van Dijk and Wilke (1994) and by Hofmeyr et al. (2007). Van Dijk and Wilke (1994) show that agents with a high endowment contribute more than agents with a low endowment. According to them, this is due to status. Agents with a high endowment think that they are expected to contribute more money to the public good ("Noblesse oblige").[11] Two reasons can explain their result. First, in their experiment, choices are not incentivized. Subjects are paid a fixed amount of 10 Dutch guilders for participating in their experiment. Second, the game is played only once. As no specific analysis of period one is realized in Buckley and Croson (2006); Reuben and Riedl (2013); Keser et al. (2013); Georgantzis and Proestakis (2011), this effect may exist in period one and fade away over time. In Hofmeyr et al. (2007) high endowed agents contribute significantly

[11]This result is also in line with what other-regarding preferences theories predict.

more than low endowed ones. Two articles highlight what they call a "fair share". In Buckley and Croson (2006), subjects' contribution represents around one fourth of the sum of contributions of every group member. In Hofmeyr et al. (2007), subjects tend to contribute another kind of "fair share". This "fair share" is a contribution relative to the *ex ante* share of wealth. Subjects with a low endowment have initially 19% of the aggregated wealth while subjects with a high endowment have 31% of the aggregated wealth. Low endowed subjects average contribution is close to 21% of the total group contribution when high endowed subjects average contribution is close to 29% of the total group contribution.

Observation 4: The origin of the endowment - either earned or randomly attributed - leads to mixed evidence.

Van Dijk and Wilke (1994) build their research hypothesis on the Equity Theory. According to this theory, agents may think that when *ex ante* levels of effort (input) are different between group members, *ex post* payoffs (output) should be different. In one treatment, individual endowment is windfallen (randomly attributed) - in other words, the level of effort provided *ex ante* is identical between high endowed and low endowed group members. In another treatment, endowment depends on the *ex ante* level of effort provided. The authors show that when subjects earn their endowment, they tend to contribute less to the public good than when endowments come from pure randomness. In another experiment, Cherry et al. (2005) test the same research hypothesis and find no significant differences between contributions behaviours of agents who earn their endowment through a quiz and contributions behaviours of agents who randomly get their endowment.

Observation 5: To the best of my knowledge, only one article focuses on the strength of the inequalities (Keser et al., 2013).[12] They find a negative effect of inequalities.

[12] By inequalities, I mean the difference in initial endowment within a group. Inequalities can be measured with GINI coefficient.

Keser et al. (2013) study the aggregated and individual levels of contributions of group members in three environments: a homogeneous treatment, a treatment with low inequalities, and a treatment with high inequalities. The aggregated level of wealth is the same in the three treatments. In the homogeneous treatment, four subjects have the same endowment (15 ECU). In the treatment with low inequalities, one subject has 10 ECU, two subjects have 15 ECU and the last subject has 20 ECU. In the treatment with high inequalities, 3 subjects have 8 ECU while the last one has 36 ECU. Average and median contributions are not significantly different in the homogeneous treatment and in the treatment with low inequalities. Average and median contributions are significantly lower in the treatment with high inequalities in comparison to the homogeneous treatment, and (weakly) significantly lower in comparison to the treatment with low inequalities. High endowed subjects do not contribute more than low endowed ones even in the environment with high inequalities.
The authors argue that it is a consequence of the calibration of the game. Subjects with 36 ECU obtain a payoff of 36 ECU when every subject within a group plays the Nash Equilibrium. In contrast, when all subjects contribute their full endowment, they have a final payoff of 30 ECU. It explains why high endowed subjects have no interest to contribute more than the endowment of the low endowed subjects: 8 ECU.

Despite a normative conflict strengthened when agents within a group are heterogeneous in endowment, the standard patterns of cooperation are observed. Contributions are not lower (5 articles out of 7) in a heterogeneous environment with respect to the homogeneous one and decrease over time. Regarding individual contribution behaviours, in contrast to what Fehr and Schmidt (1999) predict, agents with a high endowment do not contribute more than agents with a low endowment. Agents opt for equality of contributions over equality of earnings. This leads to substantial underprovision of public goods.

Articles	N	Periods	Parameters of heterogeneity	Results
Heterogeneity in endowment				
Van Dijk and Wilke (1994)	4	1	$e_1 = e_2 = 25$ and $e_3 = e_4 = 50$	High endowed subjects contribute more than low endowed ones. The effect is weakened when subjects earn their endowment. No comparison with a homogeneous treatment.
Cherry et al. (2005)	4	1	$e_1 = 10$ $e_2 = 20$ $e_3 = 30$ $e_4 = 40$	Comparison between same endowment levels within homogeneous and heterogeneous population. Contributions are lower in the heterogeneous treatment. No effect of endowment origin.
Buckley and Croson (2006)	4	10 (partner-matching protocol)	$e_1 = e_2 = 25$ and $e_3 = e_4 = 50$	High endowed subjects contribute the same amount as low endowed one. Lower share of endowment contributed for high endowed subjects. Contributions decrease over time.
Hofmeyr et al. (2007)	4	6 (partner-matching protocol)	$e_1 = e_2 = 30$ and $e_3 = e_4 = 50$ and $\forall i, e_i = 40$	Both types of agents contribute the same share to the PG. No effect of heterogeneity on efficiency. Agents seem to contribute a "fair share".
Burns and Visser (2006)	4	6 (partner-matching protocol)	$e_1 = e_2 = 30$ and $e_3 = e_4 = 50$ and $\forall i, e_i = 40$	Heterogeneity increases contributions. Pool of subjects: Subjects are fishers from South Africa.
Heap et al. (2016)	3	20 (partner-matching protocol)	$e_1 = 20, e_3 = 50$ and $e_3 = 80$	Agents with an endowment of 20 ECU or 50 ECU contribute the same amount in both treatments. Lower contributions of the richest agent in the heterogeneity treatment.
Keser et al. (2013)	4	25 (partner-matching protocol)	$\forall i, e_i = 15$ $e_1 = 10, e_2 = e_3 = 15, e_4 = 20$ $e_1 = e_2 = e_3 = 8$ and $e_4 = 36$	Contributions decrease over time. No difference between low inequalities and homogeneity. High inequalities are associated with lower contributions.
Reuben and Riedl (2013)	3	10 (partner-matching protocol)	$e_1 = e_2 = 20$ and $e_3 = 40$ $\forall i, e_i = 20$	No difference between high endowed and low endowed subjects.
Georgantzis and Proestakis (2011)	4	1	$e_1 = e_2 = 10$ and $e_3 = e_4 = 20$ $\forall i, e_i = 10$ $\forall i, e_i = 20$	High endowed subjects contribute more in absolute terms than low endowed ones. Heterogeneity leads to higher contributions. Public Information leads to lower cooperation.
Prediger (2011)	4	6 (partner matching protocol)	$e_1 = e_2 = 20$ and $e_3 = e_4 = 40$ and $\forall i, e_i = 30$	Heterogeneity increases contributions. Low endowed subjects contribute more than high endowed ones. Pool of subjects: Subjects are rural dwellers from southern Namibia.

Figure 1.1 – Calibration and results: heterogeneity in endowment

1.2.2 Heterogeneity in MPCR

Two remarks have to be done at the beginning of this section.[13] First, I choose to focus on PGGs with heterogeneity in MPCR and I let the "productivity" approach aside.[14] Second, in this section, I distinguish two kinds of heterogeneous groups: (i) groups with heterogeneity in MPCR but with MPCR lower than one for all group members, and (ii) *privileged groups* in which one group member has a MPCR higher than one such as her best response is to contribute her full endowment.

1.2.2.1 Heterogeneity in MPCR with no privileged groups

Observation 0: Heterogeneity in MPCR strengthens the normative conflict.

Reuben and Riedl (2013) observe a large heterogeneity in third parties' responses about the contribution behaviour subjects should adopt when agents are heterogeneous in MPCR. 16% of third parties favour equality of contributions, 24% of them favour contributions proportional to MPCR, 29% of them favour equality of earnings and 31% of them favour another rule of contributions (different from efficiency). Efficiency is not chosen for groups of agents heterogeneous in MPCR because it generates inequalities that do not exist *ex ante*. Additionally, Nikiforakis et al. (2012) and Gangadharan et al. (2017) show that high MPCR agents favour equality in contributions while low MPCR agents favour equality in earnings.

Observation 1: 4 articles out of 5 do not find lower aggregated contributions when agents within a group are heterogeneous in MPCR.

The first paper that investigates the effects of heterogeneity in MPCR on contributions was realized by Fisher et al. (1995). In this paper, in the heterogeneous treatment, groups are composed of two agents who have a high MPCR and two agents who have a low MPCR. They run two homogeneous control treatments in which every agent has

[13] The calibration and the principal results of every cited article in this section are presented in Figure 1.2.

[14] For related articles on PGGs with heterogeneity in productivity or in abatement cost, read Tan (2008), Noussair and Tan (2011), McGinty and Milam (2013) and Brick et al. (2016).

either the low MPCR or the high MPCR. They consider three possibilities. First case, heterogeneity in MPCR is associated with no effect. Second case, there is a positive effect of heterogeneity on aggregated contributions due to "seeding". Subjects with a high MPCR contribute more and, in order to reciprocate, subjects with a low MPCR increase their contributions. Third case, there is a negative effect of heterogeneity on aggregated contributions due to "poisoning of the wealth". Subjects with a low MPCR contribute less, and, in order to reciprocate, subjects with a high MPCR decrease their contributions. They find that the aggregated level of contributions in the heterogeneous treatment is bounded by the two homogeneous treatments. Recently, other studies (Kube et al., 2015; Molis et al., 2016; Gangadharan et al., 2017) have found no differences in aggregated contributions when comparing heterogeneous groups and homogeneous ones.

To the best of my knowledge, only Fischbacher et al. (2014) find that heterogeneity in MPCR is associated with lower unconditional contributions. In their study, Fischbacher et al. (2014) focus both on conditional and unconditional contributions in situations in which agents within a group can be either homogeneous or heterogeneous in MPCR. Regarding conditional contributions, the authors find that subjects with a high MPCR contribute more than subjects in the baseline treatment (in which the MPCR is equal to the mean value between low and high MPCR), and subjects with a low MPCR contribute less than them. Average conditional contributions are not significantly different in the heterogeneous treatment with respect to the homogeneous one. Additionally, the authors find that the effects of heterogeneity on conditional contributions are very different across subjects' type. Free-riders do not change their conditional contributions behaviour across treatments. However, the effect of heterogeneity on conditional cooperators is much more complex. If one third of the conditional cooperators do not change their conditional contributions behaviour when heterogeneity is implemented, the others choose to play differently. 17% of them increase their conditional contributions when they have a high MPCR and decrease their conditional contributions when they have a low MPCR. The others react only when they cope with one of the two situations. For example, a conditional cooperator may be insensitive to an increase in MPCR but may reduce her conditional contributions when she copes with a low MPCR. Two types of conditional cooperators decrease their contributions in the heterogeneous case: the ones who dislike heterogeneity, and the ones who compare their payoff only with high MPCR agents. The authors conclude that the lower unconditional contributions observed in their paper are not due to different other-regarding preferences across treatments but to pessimistic beliefs about other group members' average contribution. Agents may believe that other group members' contributions are likely to be lower in the heterogeneous treatment and consequently decrease their own contributions. Another reason raised by the authors lies in the normative approach. As a norm of contribution is not straightforward (because of the normative conflict), agents may have difficulty to coordinate on a contribution behaviour.

Observation 2: Contributions decrease over time.

In every article with repeated PGG, the authors that investigate the relation between time and contributions find a decrease in contributions over time (Molis et al., 2016; Reuben and Riedl, 2013; Kube et al., 2015; Gangadharan et al., 2017).

Observation 3: Agents with a high MPCR contribute more than agents with a low MPCR.

Isaac and Walker (1988) first find that in homogeneous groups, even in a one-shot game, agents are affected by the value of the MPCR and contribute more when the MPCR is high. This result has been replicated in heterogeneous environments by Fisher et al. (1995); Reuben and Riedl (2013); Fischbacher et al. (2014); Kube et al. (2015); Molis et al. (2016); Gangadharan et al. (2017). Furthermore, Fisher et al. (1995) give evidence that high MPCR agents tend to contribute more in a homogeneous treatment than in a heterogeneous one and that low MPCR agents tend to contribute less in a homogeneous treatment with respect to a heterogeneous one.

At this stage, I find (i) that heterogeneity in MPCR within a group strengthens normative conflict and (ii) that aggregated results are similar when agents differ in endowment and when agents differ in MPCR. The main difference occurs at the individual level: agents with a high MPCR contribute more than agents with a low MPCR. Both situations are characterized by a significant underprovision of the public goods.

1.2.2.2 Heterogeneity in MPCR with privileged groups

At first glance, aggregated contributions to the public good are not impacted by heterogeneity in MPCR. However, what happens when one agent within the group is privileged (i.e. has a MPCR higher than one)? This situation potentially toughens even more the normative conflict. Do privileged agents except other group members to contribute the same amount than them? In order to answer this question, I review below three articles in details.

Glöckner et al. (2011) compare the contributions in two PGGs with heterogeneity. In one treatment, groups are heterogeneous in MPCR but every agent has a MPCR lower than one. In the other treatment, agents are in a privileged group: one group member has a MPCR higher than one. The authors show that high MPCR subjects contribute significantly more in the privileged groups. However, the sum of contributions within groups is not significantly different in the two treatments. This result is explained by low MPCR subjects who contribute significantly more in groups with no privileged agents. In the treatment with no privileged groups, low MPCR subjects reciprocate to the contribution of the high MPCR agent. For each token contributed by the high MPCR subject to the public good, low MPCR subjects increase their own contributions in this treatment. In contrast, every token contributed by the high MPCR subject leads to a decrease in contributions of low MPCR subjects in the treatment with privileged groups. This result is not observed in the entire literature. In their experiments, Reuben and Riedl (2009) compare two treatments. In the first treatment, agents are in privileged groups: two agents benefit from a low MPCR and the other agent benefits from a MPCR higher than one. In the second treatment, agents are homogeneous and every agent benefits from the same MPCR (the low one). Reuben and Riedl (2009) find that (i) aggregated contributions are higher in privileged groups than in homogeneous ones and (ii) that subjects with a low MPCR contribute the same amounts in the two treatments. Interestingly, contributions of the high MPCR subjects are positively correlated with the contributions of the low MPCR subjects in the previous round. Consequently, high MPCR subjects do not always contribute their full endowment even when it is their best response to do so. High MPCR subjects seem to reciprocate to low MPCR subjects' contributions and may lower their contributions to "punish" them in case of low contributions.

In Kölle (2015), the author compares a situation of homogeneity in a PGG with two situations of heterogeneity with privileged groups: heterogeneity in MPCR and heterogeneity in productivity. In the homogeneous treatment and in the treatment with heterogeneity in MPCR, contributions tend to decrease over time and are not significantly different. However, in the treatment with heterogeneity in productivity, contributions do not decrease over time and are significantly higher than in the two other treatments. The difference in contributions observed is mainly explained by the behaviour of low type subjects that contribute more in the treatment with heterogeneity in productivity than in the treatment with heterogeneity in MPCR. It may be explained by the fact that (i) in the treatment with heterogeneity in productivity, low type subjects do not increase inequalities when they contribute to the public good, and (ii) because they benefit a lot more from "High Type" agent's contribution and contribute to reciprocate. Indeed, while low type subjects contribute an amount on average equals only to 33% of high type subjects' contributions in the heterogeneity in MPCR treatment, they contribute an amount on average equals to 78% of high type subjects' contributions in the heterogeneity in productivity treatment.[15]

[15]It is hard to compare aggregated contributions in the homogeneous treatment and the aggregated contributions in the heterogeneous ones because of the difference in efficiency. For instance, in Kölle (2015), in the homogeneous one, the full cooperation situation leads to an aggregate wealth equals to 90 ECU, while in the heterogeneous ones, it leads to an aggregate wealth equals to 150 ECU. A concern for efficiency may explain the differences observed in aggregated contributions.

Articles	N	Periods	Parameters of heterogeneity	Results
Heterogeneity in MPCR: No privileged groups				
Fisher et al. (1995)	4	2x10 (partner-matching protocol)	$\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0.3$ $\alpha_1 = \alpha_2 = 0.3$ and $\alpha_3 = \alpha_4 = 0.75$ $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0.75$	In the heterogeneous treatment, contributions are bounded by the two homogeneous treatments. High MPCR agents contribute more than low MPCR agents.
Molis et al. (2016)	4	10 (partner-matching protocol)	$\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0.5$ $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0.75$ $\alpha_1 = \alpha_2 = 0.5$ and $\alpha_3 = \alpha_4 = 0.75$	The higher the MPCR, the higher the contributions. Heterogeneity is not associated with lower contributions. Contributions decrease over time.
Kube et al. (2015)	3	20 (partner-matching protocol)	$\alpha_1 = \alpha_2 = \alpha_3 = \frac{2}{3}$ $\alpha_1 = 0.5, \alpha_2 = \alpha_3 = 0.75$	Heterogeneity is not associated with lower contributions. High MPCR agents contribute more than low MPCR agents. Contributions decrease over time.
Gangadharan et al. (2017)	6	20 (partner-matching protocol)	$\alpha_1 = \alpha_2 = \alpha_3 = 0.2, \alpha_4 = \alpha_5 = \alpha_6 = 0.4$ $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = 0.3$	Heterogeneity is not associated with lower contributions. High MPCR agents contribute more than low MPCR agents. Contributions decrease over time.
Fischbacher et al. (2014)	4	6 repeated one-shot	$\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0.4$ or $\alpha_1 = \alpha_2 = 0.3$ and $\alpha_3 = \alpha_4 = 0.5$	Heterogeneity is associated with lower unconditional contributions. Heterogeneity is not associated with lower conditional contributions.
Reuben and Riedl (2013)	4	25 (partner-matching protocol)	$\alpha_1 = \alpha_2 = \alpha_3 = 0.5$ $\alpha_1 = \alpha_2 = 0.5$ and $\alpha_3 = 0.5$	High MPCR agents contribute more than low MPCR agents. Contributions decrease over time.
Heterogeneity in MPCR: Privileged groups				
Glöckner et al. (2011)	4	20 (partner-matching protocol)	$\alpha_1 = \alpha_2 = \alpha_3 = 0.4, \alpha_4 = 0.9$ $\alpha_1 = \alpha_2 = \alpha_3 = 0.4, \alpha_4 = 1.4$	Same efficiency in both treatments. High MPCR agents contribute more when they have a MPCR equals to 1.4. Low MPCR agents are more reciprocal when high type agent's MPCR < 1.
Reuben and Riedl (2009)	3	10 (partner-matching protocol)	$\alpha_1 = \alpha_2 = 0.5, \alpha_3 = 1.5$ $\alpha_1 = \alpha_2 = \alpha_3 = 0.5$	Contributions are higher within the privileged groups. Low MPCR agents contribute the same amount in the two treatments. Contributions of high MPCR agents are correlated with others' contributions.
Kölle (2015)	3	10 (partner-matching protocol)	$\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0.5$ $\alpha_1 = \alpha_2 = \alpha_3 = 0.5, \alpha_4 = 1.5$	Heterogeneity in MPCR is not associated with lower contributions. High MPCR agents contribute more than low MPCR agents. Contributions decrease over time.

Figure 1.2 – Calibration and results: Heterogeneity in MPCR

1.3 Effects of efficiency-enhancing mechanisms on cooperation in PGGs with a heterogeneous population

So far, I have found that even if heterogeneity does not lead to a decrease in efficiency with respect to the homogeneous baseline, there is a large underprovision of public goods. Some mechanisms have been proven to be efficient to overcome the underprovision observed in PGGs with homogeneous agents (Chaudhuri, 2011). Do these mechanisms allow groups with heterogeneous agents to reach efficiency when these agents do not agree on the contribution rule they should adopt? This is the question I tackle in this part.

1.3.1 Heterogeneity in endowment and mechanisms

Observation 1: Punishment seems to be at least as efficient within groups composed of agents heterogeneous in endowment as within groups composed of agents homogeneous in endowment.

Using field experiments in developing countries, Burns and Visser (2006) and Prediger (2011) study the effects of punishment on contributions in PGGs .[16] Within fishing communities in South Africa, Burns and Visser (2006) test the effects of punishment in two treatments. In the first treatment, groups are composed of agents homogeneous in endowment. In the second treatment, groups are composed of agents heterogeneous in endowment. They find that punishment is more efficient to increase contributions in the heterogeneous treatment than in the homogeneous one. Social welfare is also significantly higher in the heterogeneous treatment than in the homogeneous one. Worst, punishment decreases social welfare in the homogeneous treatment. In heterogeneous groups, subjects with a low endowment (i) contribute a higher share of their endowment than subjects with a high endowment, (ii) punish with the same amount of tokens than subjects with a high endowment (even if their relative cost is larger because they have

[16] For an article with a threshold public good game, heterogeneity in endowment and punishment, see Robbins (2015).

not the same capacity to punish). Finally, when agents differ in endowment, punishment leads to a society with lower inequalities. Initially, low endowed subjects are 40% poorer than high endowed ones. After the punishment round, they are only 16.7% poorer than high endowed subjects.

Prediger (2011) finds that, surprisingly, punishment does not increase aggregated contributions neither in the homogeneous treatment nor in the heterogeneous one. However, both pro-social punishment - punishment against free-riders - and anti-social punishments - punishment against contributors - happen more frequently and more vehemently in the homogeneous treatment. In the homogeneous treatment, revenge emerges and leads to counter punishment while it does not in the heterogeneous treatment. Consequently, social welfare is significantly higher in the heterogeneous treatment than in the homogeneous one when punishment is introduced. There is no difference in the intensity of punishment between subjects with a low endowment and subjects with a high endowment. The author concludes that punishment is not accepted among a non marginal part of the subjects - rural dwellers from Southern Namibia.

The two articles above indicate that punishment leads to a higher social welfare when agents are heterogeneous in endowment. However, this promising result has been found in two very specific environments. Other articles have tried to study the effects of punishment in a more standard setting. First, there are Reuben and Riedl (2013), who focus on normative conflict. They study three different treatments.[17] In the first treatment, agents within a group are homogeneous in endowment. In the second treatment, agents within a group differ in endowment. In the third treatment, agents differ in endowment (with the same calibration than in the second treatment), but have the same capacity to contribute to the public good (equals to the low endowment). Implementing punishment leads to an increase in contributions. In both heterogeneous treatments, 4 groups out of 11 reach the Pareto dominant situation during at least 5 periods (out of 10). Punishment allows groups to overcome the standard decrease

[17] In the final treatment, agents differ in MPCR. Results about this treatment will be presented in Section 1.3.2.

of contributions over time. Interestingly, in the treatment with heterogeneous agents who have no capacity constraints, it seems normal for subjects that those with twice as much endowment contribute twice as much as others. It is however not the case in the heterogeneous treatment with capacity constraints. Reuben and Riedl (2013) explain that most often, subjects favour efficiency over equality. Even if it was possible to let the high endowed agent contributes twice as much as other subjects, the "loss" in efficiency would have been too important. Unfortunately, in this article, it is not possible to compare the heterogeneous treatments with the homogeneous one because aggregated wealth changes across conditions.[18]

Finally, Weng and Carlsson (2015) study the interaction between identity and punishment within both homogeneous groups and heterogeneous ones. Subjects fulfil a questionnaire which determines their endowment level. In the treatments with neither punishment nor identity, heterogeneous agents contribute 31% of their endowment whereas homogeneous agents contribute 49% of their endowment.[19] While inducing identity does not increase contributions in homogeneous groups, it increases contributions, going from 31% to 46% of endowment, in heterogeneous groups. In other words, the good news is that "identity" can counter the detrimental effects of heterogeneity observed in this game at almost null cost. What about punishment? Punishment is equally efficient in situations with weak or strong identity and increases contributions to an average of around 70% of total endowment. Building a strong identity is useful only when agents have no possibility to punish.

[18]Note that a simple calculation leads to these results: contributions are equal to 81.1% of the total endowment available in the homogeneous treatment, to 73.86% of the total endowment available in the heterogeneous treatment with no capacity constraints, and to 77.8% of the total endowment available in the heterogeneous treatment with capacity constraints.

[19]I do not report this article in Section 1.2.1 because no statistical test is done regarding these two values.

1.3.2 Heterogeneity in MPCR and mechanisms

1.3.2.1 Mechanisms and heterogeneity in MPCR with no privileged groups

Observation 1: Punishment seems to be less efficient within groups composed of agents heterogeneous in MPCR than within groups composed of homogeneous agents.

Reuben and Riedl (2013) find that although the quantity of punishment is not different across treatments, contributions seem to be lower in the treatment with heterogeneity in MPCR (contributions level: 65%). Efficiency is associated with *ex post* inequalities that are not accepted by low MPCR agents. Yet, even if the normative conflict is important, 40% of groups succeed to reach the Pareto dominant strategy in at least 5 periods. When they consider the whole game, the difference in contributions between high MPCR subjects and low MPCR subjects is not significant. The low efficient groups are characterized by low MPCR subjects that try to implement an equality-of-earnings norm when high MPCR subjects try to implement an equality-of-contributions norm. This pattern may be explained by the self-serving approach of the norm: agents try to enforce the norm that maximizes their own earnings.

By comparing a PGG with homogeneous agents and a PGG with agents heterogeneous in MPCR, Nikiforakis et al. (2012) want to observe if normative conflicts are likely to encourage feuds - a situation in which social welfare is destroyed. In order to signal their disagreement about the contributions chosen by other group members, subjects have the possibility to punish at almost a null cost (1 token allows subjects to punish as much as they want). Moreover, subjects have the possibility to counter punish as long as they want and as long as other subjects have a positive payoff. The authors finally show (i) that subjects generally value more equality in *ex post* payoffs than equality in contributions, (ii) that heterogeneity in MPCR leads to three times more feuds than homogeneity in MPCR, and (iii) that although punishment leads to an increase in contributions in the heterogeneous treatment, it does not lead to an increase in social welfare because of the money destroyed by punishment. Additionally, the authors observe that high MPCR subjects contribute significantly more than low MPCR subjects. Consequently, subjects with a high MPCR punish subjects with a low MPCR and this is often the origin of feuds. This article highlights the difficulty to encourage self-governance in communities with heterogeneity in MPCR.

Observation 2: Vote leads to an increase in efficiency less important within groups with agents heterogeneous in MPCR than within groups with agents homogeneous in MPCR.

After observing underprovision of public goods in a standard environment, Kube et al. (2015) investigate the effects of vote and institutions formation in a PGG. According to the authors, one way to overcome underprovision is to align individual interest with collective interest. In order to do this, it is possible to implement an institution through vote. In their article, an institution takes the form of a rule of contribution. As the vote is binding, if no group members go against the decision, then agents may secure a better payoff than the one associated to Nash Equilibrium. Of course, agents may be opposed to the vote, because it has a binding nature that reduces the set of possible choices. Do groups accept to vote, and succeed to implement a rule of contributions? Two kind of groups are compared: one in which agents are homogeneous in MPCR and another in which they are heterogeneous in MPCR. In principle, it is easier to have unanimity in homogeneous groups, in which efficiency leads to equality in payoff. In the case of heterogeneous groups, the authors wonder which rule will be preferred and chosen. Will they accept a rule based on efficiency even if it generates inequalities, or will they prefer to vote for a rule that guarantees equality in earnings at the cost of a loss in efficiency? The two populations are compared in three treatments (2x3 design): a standard PGG, and two treatments with vote. Treatments are implemented in a between subjects manner. In the first treatment with vote, subjects have the possibility to vote to contribute their whole endowment to the public good (VOTE-SYM). This institution maximizes efficiency but triggers inequalities within the heterogeneous groups. Consequently, the authors show, using Fehr and Schmidt (1999) framework, that inequality averse agents may vote against the implementation of this institution when there is heterogeneity in MPCR within the group. In the second treatment with vote, subjects have the possibility to implement an institution in which two group members know that they will contribute their whole endowment when the third subject will contribute only a part of her endowment (VOTE-ASYM). This treatment guarantees equality of earnings within the groups with heterogeneity in MPCR. The institution is binding and is implemented only if there is unanimity in votes. If the institution is not unanimously accepted, a standard PGG is played in a second stage. The authors find that, in the homogeneous treatment, subjects agree to vote for the institution that enforces efficient contributions. The institution is implemented in 86.6% of the periods. Consequently, VOTE-SYM leads to an increase in efficiency with respect to the standard PGG with no vote possibility when groups are composed of agents homogeneous in MPCR. Within heterogeneous groups, as predicted theoretically, the institution that maximizes social welfare is less frequently implemented (56.3% of the time). This low rate of implementation is explained by low MPCR subjects that vote for this institution only 59.7% of the time. VOTE-SYM is less efficient when subjects are heterogeneous in MPCR than when subjects are homogeneous, but is still more efficient than when heterogeneous groups have no possibility to vote. VOTE-ASYM is more popular in heterogeneous groups since the institution is implemented in 77.2% of the periods. If high MPCR subjects significantly prefer to vote for VOTE-SYM, they still are numerous to vote for vote VOTE-ASYM when it is possible (95.9% vs 89.5%). Although VOTE-ASYM is chosen more frequently, the institution leads to the same level of efficiency that VOTE-SYM for heterogeneous groups.[20] Naturally, VOTE-ASYM is only implemented in 27.6% of the periods in homogeneous groups. Indeed, in this case, the institution is not only inefficient but also triggers inequalities. For homogeneous groups, VOTE-ASYM does not increase efficiency in comparison to the standard PGG. To conclude, groups who do not succeed to reach a unanimous agreement do not play differently in the second stage in comparison to the baseline treatment when they have no vote possibility. The only exception happens when homogeneous subjects do not reach an agreement

[20]This is in part due to the mechanical loss of efficiency in VOTE-ASYM due to lower contributions of the low MPCR agent.

in VOTE-SYM. In this case, subjects contribute significantly less in the second stage in comparison to the baseline treatment.

Altogether, these results suggest that heterogeneous agents are able to implement institutions. They privilege equality of payoffs over efficiency but still find their way to increase social welfare when they have the opportunity to vote. Nonetheless, the authors highlight the fact that groups are only composed of three members. Unanimity is much more complicated to reach, and therefore, the implementation of institutions is less likely to be observed when the number of agents increases within a group.

Observation 3: Even when agents have the opportunity to privilege efficiency and no inequalities they do not succeed to reach this strategy.

In Gangadharan et al. (2017), the authors study the effects of communication added to rewards on contributions in PGGs. While the Pareto dominant strategy leads to inequalities that will not be accepted by the whole group when agents within a group differ in MPCR, the authors offer the possibility to communicate through a chat box and to transfer money. If agents are inequality averse, it is possible for them to contribute an amount that leads to a situation close to the Pareto dominant situation, and then to transfer money from the richer agents to the poorer ones. This mechanism gives opportunities to fight inequalities at a minimal cost in social welfare - a new aspect of this mechanism in comparison to the standard punishment and to the vote. The authors find mixed results. First, the good news is that communication leads to an increase in contributions by 101% in heterogeneous groups. However, communication does not allow to reach the Pareto dominant situation in heterogeneous groups whereas it is the case in homogeneous ones. Starting at the same level of contributions with no communication opportunity, communication increases contributions by 265% in homogeneous groups. The implementation of communication leads to an increase by 80% in final payoffs for homogeneous groups whereas payoffs only increase by 46% within heterogeneous groups. Can it be explained by the fact that subjects in heterogeneous groups cannot agree on a contribution rule? Evidence does not go into that direction. 15

groups out of 17 have a stable pattern of contributions over time. Only 4 groups choose to privilege efficiency over equality in payoff. Rewards are significantly less used in the heterogeneous treatment, and consequently, subjects do not take advantage of this opportunity to decrease inequalities.

Altogether, the 3 observations suggest that efficiency is rarely chosen by subjects in groups with heterogeneity in MPCR. The normative conflict between high MPCR subjects and low MPCR subjects is too strong. Efficiency is intertwined with inequalities that low MPCR subjects do not accept. Even, when agents have the opportunity to maximize efficiency with no inequalities they do not take this opportunity.

1.3.2.2 Mechanisms and heterogeneity in MPCR with privileged groups

Observation 1: Within privileged groups, punishment is not efficient at increasing social welfare when agents differ in MPCR. However, when agents differ in productivity, punishment leads to an increase in social welfare.

In PGGs with privileged groups, Reuben and Riedl (2009) show that punishment may have counterproductive effects. Punishment level is not significantly different in the standard PGG with homogeneous groups and in the PGG with privileged groups. Subjects punish their counterparts that contribute less than them. Most often, a positive deviation compared to the subject's contribution - i.e. when other group members contribute more than the subject - is associated with a lower level of punishment in non privileged groups. It is not the case with PGGs with privileged groups. In other words, the privileged agent, who is most often the top contributor, is punished despite her large contributions. Subjects with a low MPCR who free-ride and who are the target of punishment increase their contributions in both treatments. Yet, the increase in contributions is higher in non privileged groups. Finally, at the aggregate level, punishment increases social welfare only in the non privileged groups. Moreover, although punishment does not increase social welfare in privileged groups, it does increase inequalities. For a low MPCR agent, it is better to be in a homogeneous group when punishment is introduced.

In Kölle (2015), the effects of punishment depend on the type of heterogeneity. If the mechanism is efficient in the treatment with heterogeneity in productivity, it is less efficient in the treatment with heterogeneity in MPCR. Indeed, while the level of contributions was identical in the treatment with heterogeneity in MPCR and in the treatment with homogeneity in MPCR before that punishment was implemented, the level of contributions becomes lower in the treatment with heterogeneity in MPCR once punishment is implemented. While in the two other treatments, contributions increase significantly when punishment is available, it is not the case in the treatment with heterogeneity in MPCR. How do agents punish in the three treatments? First of all, the level of punishment is not statistically different across treatments. However, the pattern of punishment seems to vary in the different treatments. Negative deviation in comparison to own's contribution is punished in 57%, 22% and 73% of the case respectively in the baseline treatment, in the treatment with heterogeneity in MPCR and in the treatment with heterogeneity in productivity. Consequently, negative deviation from own's contribution is more severely and systematically punished in the treatment with heterogeneity in productivity. High productivity subjects punish more low productivity subjects in the treatment with heterogeneity in productivity while low MPCR subjects punish more high MPCR subjects in the treatment with heterogeneity in MPCR - even when she contributes more than them. Mostly, it can be explained by the fact that the high MPCR subject generates inequalities when she contributes and one way to decrease inequalities for low MPCR subjects is to punish her. It can also explain why high MPCR subjects do not punish low MPCR subjects because it would increase inequalities. Finally, punishment does not increase social welfare in the baseline treatment and in the treatment with homogeneity in MPCR while punishment increases social welfare in the treatment with heterogeneity in productivity. Punishment increases inequalities in the treatment with heterogeneity in MPCR while it decreases inequalities in the treatment with heterogeneity in productivity.

1.4 Conclusion

In this article, I survey articles which focus on heterogeneity in linear PGGs. The topic has been carefully studied these recent years. As a first remark, heterogeneity can take different forms, and I first distinguish two classes of heterogeneity: heterogeneity in endowment and heterogeneity in MPCR. These two classes of heterogeneity are likely to exist in real world in which agents may differ in income or in return (young adults are likely to benefit more from the education system while the older ones are likely to benefit more from the health system). These differences in heterogeneity were likely to trigger different results due to different reactions. The first approach was logically to separate these two kinds of heterogeneity and to see how heterogeneous agents contribute to the PGG, depending on the nature of the heterogeneity.

What I learn can be summarized in a simple way. Heterogeneity exacerbates the normative conflict but does not change the standard results observed in the PGG with homogeneous agents. Agents contribute positive amounts to the public good, equal or close to the amounts contributed when agents are homogeneous. Their contributions tend do diminish over time such as at the end of the game, they are close to zero. Often, high type agents contribute more than the low type ones at the beginning of the game, but this phenomenon disappears over time for agents with a high endowment. Obviously, these results are not enough. As economists, we want to increase efficiency, and we know some mechanisms that are successful to do this with homogeneous groups. How do these mechanisms perform when agents are heterogeneous and do not agree about the contribution behaviour that the group members should adopt?

I find mixed results. When agents are heterogeneous in endowment, punishment tends to be effective. It increases contributions and social welfare and often performs as well as with homogeneous groups. When it comes to heterogeneity in MPCR, results are less conclusive. If Reuben and Riedl (2013) find that punishment increases slightly welfare, Nikiforakis et al. (2012) show that it is less efficient than in homogeneous groups. Worst, in the latter article, it may even lead to feuds and to a total destruction of social welfare. When it comes to other kinds of mechanism, results are still less satisfying. Vote and communication + rewards increase contributions but not as efficiently as in homogeneous groups. It is certainly due to the normative conflict. When in the heterogeneity in endowment treatment, efficiency leads to equality in payoffs, it is not the case in the heterogeneity in MPCR treatment. Subjects often disagree to have *ex post* inequalities, such as it generates lower contributions. Even when they have the opportunity to neutralize inequalities through communication + rewards, as in Gangadharan et al. (2017), they do not reach the maximum theoretical efficiency with no inequality. There is a need for more research about mechanisms that can be useful to help agents heterogeneous in MPCR to reach full contributions.

Bibliography

Alesina, A., R. Baqir, and W. Easterly (1999). Public goods and ethnic divisions. *The Quarterly Journal of Economics 114*(4), 1243–1284.

Alesina, A. and E. La Ferrara (2000). Participation in heterogeneous communities. *The Quarterly Journal of Economics 115*(3), 847–904.

Alesina, A. and E. La Ferrara (2002). Who trusts others? *Journal of Public Economics 85*(2), 207–234.

Algan, Y., C. Hémet, and D. D. Laitin (2016). The social effects of ethnic diversity at the local level: A natural experiment with exogenous residential allocation. *Journal of Political Economy 124*(3), 696–733.

Andreoni, J. (1995). Cooperation in public-goods experiments: kindness or confusion? *The American Economic Review*, 891–904.

Bagnoli, M. and M. McKee (1991). Voluntary contribution games: Efficient private provision of public goods. *Economic Inquiry 29*(2), 351–366.

Becker, G. S. (1974). A theory of social interactions. *Journal of Political Economy 82*(6), 1063–1093.

Bergstrom, T., L. Blume, and H. Varian (1986). On the private provision of public goods. *Journal of Public Economics 29*(1), 25–49.

Bolton, G. E. and A. Ockenfels (2000). ERC: A theory of equity, reciprocity, and competition. *The American Economic Review 90*(1), 166–193.

Brick, K., M. Visser, and Z. Van der Hoven (2016). Cooperation and climate change: Can communication facilitate the provision of public goods in heterogeneous settings? *Environmental and Resource Economics 64*(3), 421–443.

Brookshire, D., D. Coursey, and D. Redington (1993). Special interests and the voluntary provision of public goods. *Working Papers in Economics*.

Buckley, E. and R. Croson (2006). Income and wealth heterogeneity in the voluntary provision of linear public goods. *Journal of Public Economics 90*(4-5), 935–955.

Burlando, R. M. and F. Guala (2005). Heterogeneous agents in public goods experiments. *Experimental Economics 8*(1), 35–54.

Burns, J. and M. Visser (2006). Bridging the great divide in South Africa: Inequality and punishment in the provision of public goods. *Working Papers in Economics* (219).

Cardenas, J.-C. (2003). Real wealth and experimental cooperation: experiments in the field lab. *Journal of Development Economics 70*(2), 263–289.

Charness, G. and M. Rabin (2002). Understanding social preferences with simple tests. *The Quarterly Journal of Economics 117*(3), 817–869.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: a selective survey of the literature. *Experimental Economics 14*(1), 47–83.

Cherry, T. L., S. Kroll, and J. F. Shogren (2005). The impact of endowment heterogeneity and origin on public good contributions: evidence from the lab. *Journal of Economic Behavior & Organization 57*(3), 357–365.

Dekel, S., S. Fischer, et al. (2017). Potential pareto public goods. *Journal of Public Economics 146*, 87–96.

Falk, A. and U. Fischbacher (2006). A theory of reciprocity. *Games and Economic Behavior 54*(2), 293–315.

Fehr, E. and K. M. Schmidt (1999). A theory of fairness, competition, and cooperation. *The Quarterly Journal of Economics 114*(3), 817–868.

Fischbacher, U. and S. Gachter (2010). Social preferences, beliefs, and the dynamics of free riding in public goods experiments. *The American Economic Review 100*(1), 541–56.

Fischbacher, U., S. Schudy, and S. Teyssier (2014). Heterogeneous reactions to heterogeneity in returns from public goods. *Social Choice and Welfare 43*(1), 195–217.

Fisher, J., R. M. Isaac, J. W. Schatzberg, and J. M. Walker (1995). Heterogenous demand for public goods: Behavior in the voluntary contributions mechanism. *Public Choice 85*(3-4), 249–266.

Gangadharan, L., N. Nikiforakis, and M. C. Villeval (2017). Normative conflict and the limits of self-governance in heterogeneous populations. *European Economic Review 100*, 143–156.

Georgantzis, N. and A. Proestakis (2011). Accounting for real wealth in heterogeneous-endowment public good games. *Working Papers in Economics*.

Glöckner, A., B. Irlenbusch, S. Kube, A. Nicklisch, and H.-T. Normann (2011). Leading with (out) sacrifice? a public-goods experiment with a privileged player. *Economic Inquiry 49*(2), 591–597.

Heap, S. P. H., A. Ramalingam, and B. V. Stoddard (2016). Endowment inequality in public goods games: A re-examination. *Economics Letters 146*, 4–7.

Hofmeyr, A., J. Burns, and M. Visser (2007). Income inequality, reciprocity and public good provision: an experimental analysis. *South African Journal of Economics 75*(3), 508–520.

Houser, D. and R. Kurzban (2002). Revisiting kindness and confusion in public goods experiments. *The American Economic Review 92*(4), 1062–1069.

Isaac, R. M. and J. M. Walker (1988). Group size effects in public goods provision: The voluntary contributions mechanism. *The Quarterly Journal of Economics 103*(1), 179–199.

Kachelmeier, S. J. and M. Shehata (1997). Internal auditing and voluntary cooperation in firms: A cross-cultural experiment. *Accounting Review*, 407–431.

Keser, C., M. Schmidt, A. Markstädter, and C. Schnitzler (2013). Rich man and lazarus–: Asymmetric endowments in public-good experiments. *Working Papers in Economics*.

Kingsley, D. C. (2016). Endowment heterogeneity and peer punishment in a public good experiment: Cooperation and normative conflict. *Journal of Behavioral and Experimental Economics 60*, 49–61.

Kölle, F. (2015). Heterogeneity and cooperation: The role of capability and valuation on public goods provision. *Journal of Economic Behavior & Organization 109*, 120–134.

Kube, S., S. Schaube, H. Schildberg-Hörisch, and E. Khachatryan (2015). Institution formation and cooperation with heterogeneous agents. *European Economic Review 78*, 248–268.

Kurzban, R. and D. Houser (2005). Experiments investigating cooperative types in humans: A complement to evolutionary theory and simulations. *Proceedings of the National Academy of Sciences 102*(5), 1803–1807.

Ledyard, J. O. (1995). *Public Goods: A Survey of Experimental Research. S. 111–194 in: J. Kagel/A. Roth (Hrsg.), Handbook of Experimental Economics*. Princeton: Princeton University Press.

Marwell, G. and R. E. Ames (1979). Experiments on the provision of public goods. i. resources, interest, group size, and the free-rider problem. *The American Journal of Sociology 84*(6), 1335–1360.

Marwell, G. and R. E. Ames (1980). Experiments on the provision of public goods. ii. provision points, stakes, experience, and the free-rider problem. *The American Journal of Sociology 85*(4), 926–937.

McGinty, M. and G. Milam (2013). Public goods provision by asymmetric agents: experimental evidence. *Social Choice and Welfare 40*(4), 1159–1177.

Miguel, E. (2004). Tribe or nation? nation building and public goods in Kenya versus Tanzania. *World Politics 56*(3), 327–362.

Miguel, E. and M. K. Gugerty (2005). Ethnic diversity, social sanctions, and public goods in kenya. *Journal of Public Economics 89*(11-12), 2325–2368.

Molis, E., L. Neyse, and R. Peña-Fernandez (2016, February). Heterogeneous Returns and Group Formations in the Public Goods Game. *Working Papers in Economics* (16/02).

Nikiforakis, N. and H.-T. Normann (2008). A comparative statics analysis of punishment in public-good experiments. *Experimental Economics 11*(4), 358–369.

Nikiforakis, N., C. N. Noussair, and T. Wilkening (2012). Normative conflict and feuds: The limits of self-enforcement. *Journal of Public Economics 96*(9-10), 797–807.

Noussair, C. N. and F. Tan (2011). Voting on punishment systems within a heterogeneous group. *Journal of Public Economic Theory 13*(5), 661–693.

Palfrey, T. R. and J. E. Prisbrey (1997). Anomalous behavior in public goods experiments: How much and why? *The American Economic Review*, 829–846.

Prediger, S. (2011). How does income inequality affect cooperation and punishment in public good settings? *Working Papers in Economics*.

Rabin, M. (1993). Incorporating fairness into game theory and economics. *The American Economic Review*, 1281–1302.

Rapoport, A. and R. Suleiman (1993). Incremental contribution in step-level public goods games with asymmetric players. *Organizational Behavior and Human Decision Processes 55*(2), 171–194.

Reuben, E. and A. Riedl (2009). Public goods provision and sanctioning in privileged groups. *Journal of Conflict Resolution 53*(1), 72–93.

Reuben, E. and A. Riedl (2013). Enforcement of contribution norms in public good games with heterogeneous populations. *Games and Economic Behavior 77*(1), 122–137.

Robbins, T. (2015). Punishment, inequality, and heterogeneous risk in threshold public goods games: Tackling the climate change social dilemma. *Working Papers in Economics*.

Tan, F. (2008). Punishment in a linear public good game with productivity heterogeneity. *De Economist 156*(3), 269–293.

Van Dijk, E. and H. Wilke (1994). Asymmetry of wealth and public good provision. *Social Psychology Quarterly*, 352–359.

Warr, P. G. (1983). The private provision of a public good is independent of the distribution of income. *Economics Letters 13*(2-3), 207–211.

Weng, Q. and F. Carlsson (2015). Cooperation in teams: The role of identity, punishment, and endowment distribution. *Journal of Public Economics 126*, 25–38.

Zelmer, J. (2003). Linear public goods experiments: A meta-analysis. *Experimental Economics 6*(3), 299–310.

A Appendix

A.1 Proofs

Proof 1 - Heterogeneity in endowment and absolute contribution

Let's assume the existence of two agents with endowment such as $e_i > e_j$. Let's show that in order to equalize payoff of both members, we need to have $c_i > c_j$.

$$\pi_i(c_i) = \pi_j(c_j)$$

$$\beta(e_i - c_i) + \alpha \sum_{k=1}^{N} c_k = \beta(e_j - c_j) + \alpha \sum_{k=1}^{N} c_k$$

$$(e_i - c_i) = (e_j - c_j)$$

$$(e_i - e_j) = (c_i - c_j)$$

As $e_i > e_j$, we have $c_i > c_j$.

Proof 2 - Heterogeneity in endowment and relative contribution

Let's assume the existence of two agents with endowment such as $e_i > e_j$. Let's show that in order to equalize payoff of both members, we need to have $p_i > p_j$ where $p_k = \frac{c_k}{e_k}$.

$$\pi_i(p_i) = \pi_j(p_j)$$

$$\beta(e_i - p_i \times e_i) + \alpha \sum_{k=1}^{N} c_k = \beta(e_j - p_j \times e_j) + \alpha \sum_{k=1}^{N} c_k$$

$$(e_i - p_i \times e_i) = (e_j - p_j \times e_j)$$

$$(1 - p_i) \times e_i - (1 - p_j) \times e_j = 0$$

As $e_i > e_j$, we have $(1 - p_i) < (1 - p_j)$

$$(1 - p_i) < (1 - p_j)$$

$$-p_i < -p_j$$

$$p_i > p_j$$

Proof 3 - Heterogeneity in MPCR and absolute contribution

Let's assume the existence of two agents with endowment such as $\alpha_i > \alpha_j$. Let's show that in order to equalize payoff of both members, we need to have $c_i > c_j$.

$$\pi_i(c_i) = \pi_j(c_j)$$

$$\beta(e - c_i) + \alpha_i \sum_{k=1}^{N} c_k = \beta(e - c_j) + \alpha_j \sum_{k=1}^{N} c_k$$

$$\alpha_i \sum_{k=1}^{N} c_k - \alpha_j \sum_{k=1}^{N} c_k = \beta(e - c_j) - \beta(e - c_i)$$

$$(\alpha_i - \alpha_j) \sum_{k=1}^{N} c_k = \beta(c_i - c_j)$$

As $(\alpha_i - \alpha_j) \sum_{k=1}^{N} c_k > 0$, we have $c_i > c_j$

Proof 4 - Heterogeneity in MPCR and relative contribution

Let's assume the existence of two agents with endowment such as $\alpha_i > \alpha_j$. Let's show that in order to equalize payoff of both members, we need to have $p_i > p_j$.

$$\pi_i(c_i) = \pi_j(c_j)$$

$$\beta(e - p_i \times e) + \alpha_i \sum_{k=1}^{N} c_k = \beta(e - p_j \times e) + \alpha_j \sum_{k=1}^{N} c_k$$

$$\alpha_i \sum_{k=1}^{N} c_k - \alpha_j \sum_{k=1}^{N} c_k = \beta(e - p_j \times e) - \beta(e - p_i \times e)$$

$$(\alpha_i - \alpha_j) \sum_{k=1}^{N} c_k = \beta.e \times (p_i - p_j)$$

As $(\alpha_i - \alpha_j)\sum_{k=1}^{N} c_k > 0$, we have $p_i > p_j$

Chapter 2

Cooperation in a risky world[1]

2.1 Introduction

Many economic interactions create tension between individual and collective interests. For this reason, human cooperation has become one of the central topics in behavioral economics. Since the pioneering work of Isaac et al. (1985), numerous economists have studied cooperation using the Voluntary Contribution Mechanism (VCM in short).[2] Over time, VCM has become a widely accepted experimental testbed for studying various environmental and institutional aspects of cooperation (Ledyard, 1995; Chaudhuri, 2011).

Strikingly, what has once evolved to become the "gold standard" in experimental economics – that is, a version of VCM based on a deterministic, homogeneous and publicly known personal returns from the public good – seems far off as compared not only to the seminal work by Isaac et al. (1985), but also to many real world situations. Isaac et al. (1985) use heterogeneous returns from the public good which are entirely private knowledge, a design that certainly adds realism to the experimental game.[3]

[1]This chapter is a joint work with Adam Zylbersztejn published in *Journal of Public Economic Theory*.

[2]According to another early study by Isaac et al. (1984), this seminal work dates back to 1980. Ledyard (1995) lists the study by Isaac et al. (1985) as the first economic experimental work on public goods, along Kim and Walker (1984) (who conducted their experiments two months later).

[3]Of course, using the standard design has major advantages. First, it reduces the degree of unwarranted uncertainty in the decision-making environment, thus improving the experimenter's control over subjects'

For instance, the benefits that the individuals derive from establishing public facilities for health care, education or social security are likely to be heterogeneous, private knowledge, and furthermore subject to randomness and variation over time.

Yet, relatively little is still known about how the patterns of cooperation change once the decision-making environment shifts away from the "gold standard" paradigm. Addressing this issue seems important in terms of both the internal and the external validity of laboratory experiments. First, the data from alternative settings can be informative about the robustness and the limitations of the large body of experimental findings based on the standard VCM setup. Second, as recently documented in a carefully crafted lab-in-the-field experiment by Stoop et al. (2012), the usual patterns of cooperation observed in the standard VCM may not prevail in analogous (yet involving more complexity and uncertainty) real world environments.[4] Explaining such discrepancies and rendering the findings from lab experiments applicable to naturally occurring settings calls for a greater care for the ecological validity of laboratory experiments. Our experimental is a step in that direction.

Herein, we tweak the standard VCM by incorporating two kinds of *environmental risk* which may occur either at the individual or at the group level. In both cases, the personal return from the public good is not deterministic, but probabilistic – either higher or lower than the riskless one. Both outcomes are equiprobable, become known *ex post* (i.e., only after the contribution decisions have been made), and the lottery is mean-preserving with respect to the standard VCM scenario. In the *homogeneous risk* treatment, the random draw is made in each round for the whole group. In the *heterogeneous risk* treatment, in turn, this happens in each round independently for each group member. Thus, our

decisions. Second, it makes the outcomes of different experiments easier to compare and replicate, thus fostering the accumulation of empirical knowledge.

[4]They have conducted an experiment among recreational fishermen at a private pond. There are two variations of a VCM game: a framed field game and a standard lab game. In both tasks, fishermen decide how many fish they want to catch. Abstaining from catching a fish (and thus reducing one's own welfare) generates positive externalities (which exceed that individual welfare loss) for other fishermen. They report that the usual patterns of cooperation observed in the lab game fade away in the analogous field game. They also test (and refute) a number of possible explanations behind this difference. However, one factor which they do not test is related to environmental uncertainty – in the lab VCM game, participants simply choose the number of fish, while in the field VCM game played around a fishing pond the final catch can never be certain.

experimental paradigm provides a simple way to capture the distinction between local and global environmental risks that is important in various real world public good settings.[5] Our experiment complements the previous work by Lévy-Garboua et al. (2017) who study cooperation in building a common insurance pool. In their design, agents face the risk of losing their resources and *ex ante* may voluntarily fund a group insurance scheme to help the needy members recover their losses. Herein, the risk is related to the *ex post* capacity to benefit from a common resource.

Our experiment consists of two incentivized VCM-based tasks. In the first part, we elicit players' conditional contributions to the public good, their unconditional contribution in a one-shot interaction, as well as their beliefs about other group members' contributions. In the second part, the participants play a finitely repeated VCM game under partner matching. We implement the environmental risk treatments in a between-subject manner. Given the proper randomization of social and risk preferences across experimental conditions, our investigation provides causal evidence on the effect of environmental risk on different layers of human cooperation.

Our theory builds on the insight from Krawczyk and Le Lec (2010) that social interactions in risky environments are affected by both distributive fairness (i.e., *ex post* outcomes) and procedural fairness (i.e., *ex ante* opportunities). Here, our intuition is that although different kinds of environmental risk preserve the expected value of MCPR (which should mute any concerns regarding procedural fairness), random MPCR may affect behavior through the differences in the *ex post* group inequalities (which may trigger a behavioral reaction due to distributive fairness). This hypothesis finds a rather weak support in the data. Neither the conditional contributions, nor the unconditional contributions, nor the beliefs about other group members' contributions in the one shot

[5]Going back to our previous example, one's utility from public health services may depend on idiosyncratic health hazards (such as non-infectious diseases related to one's genes, profession, or lifestyle), but also on the population-wide hazards (such as large outbreaks of infectious diseases). In a similar vein, one's benefit from public education facilities may depend on one's current educational needs or aspirations, but also on global labor market fluctuations that may render education as a whole (or at least its certain types) either beneficial or redundant. Finally, the benefits a worker derives from social security system may depend on individual risks (such as an accident at work), but also on collective risks (such as industrial restructuring resulting in large-scale lay-offs).

game vary due to environmental risk. Furthermore, the correlation between players' unconditional contributions and their beliefs about others' behavior remains stable across experimental treatments. Regarding the repeated VCM game, in all experimental conditions we observe the typical patterns of behavior: relatively high contributions in the initial round of the game, and their gradual decay over time. Heterogeneous risk has no effect on cooperation relative to the riskless control condition at any stage of the repeated game. Homogeneous risk improves cooperation relative to both remaining conditions (which stands in line with our initial hypothesis), but only in the early rounds after which this positive effect quickly fades away. Altogether, these findings suggest that standard experimental methodology provides a robust yet conservative measure of human cooperation.

2.2 Related literature

In this section, we review the economic literature which experimentally investigates how deviations from the "gold standard" design – in which the marginal per capita return (MPCR) from the public good ought to be deterministic, homogeneous and publicly known – affect cooperation in the voluntary contribution mechanism. We refer to those settings as non-standard VCM settings. Typically, a non-standard setting is achieved by adding some sort of randomness to the process that transforms decisions into outcomes. Whenever such randomness is lottery-like, i.e. it involves a finite set of outcomes with publicly known probabilities (which is the case of the present experiment), we classify it as *environmental risk*. Otherwise, a non-standard setting is said to involve *environmental uncertainty*. All these studies use a VCM game that is being repeated over multiple periods, with the exception of Fischbacher et al. (2014) who use a sequence of one-shot VCM games with varying MPCR schemes, and Björk et al. (2016) who combine these two setups just as we do in the present study[6].

[6]We have come across the working paper by Björk et al. (2016) – who use an approach similar to ours to investigate the effects of risk and uncertainty (through a binary MPCR lottery with either known or unknown probabilities) on cooperation – while finishing the present manuscript.

Our literature review suggests that the earliest experiment based on the VCM paradigm by Isaac et al. (1985) does not meet the "gold standard" criteria: even though in their experiment the MPCR is deterministic, it is also heterogeneous among players and remains privately know (which, in turn, is public knowledge). However, the most prominent studies following Isaac et al. (1985) are already based on the "gold standard" approach (see, for instance, Kim and Walker, 1984; Andreoni, 1988; Isaac and Walker, 1988a,b).

To the best of our knowledge, Fisher et al. (1995) are the first to experimentally compare standard and non-standard VCM settings. They build two control conditions based on the the standard design which only differ in the value of MPCR (which can be either high or low). In their main experimental treatment, MPCR comes with environmental uncertainty: it is heterogeneous and has an unknown distribution (even though players are aware of their own MPCR). Their main finding is that behavior is sensitive to the variations in one's own MPCR, but not to the presence of the environmental uncertainty about other players' MPCRs.[7] In a similar vein, Boulu-Reshef et al. (2017) propose an experiment in which environmental uncertainty about MPCR takes the form of an individual random draw from a uniform distribution, so that neither personal MPCR nor other players' MPCRs are known to any individual at the time of decision-making. They also report that cooperation is neutral to the presence of environmental uncertainty. Finally, in Gangadharan and Nemes (2009) the environmental uncertainty is related to whether players obtain the return from the public good or not (the probabilities of which remain unknown to players). This form of environmental uncertainty is found to hurt cooperation as compared to the analogous "gold standard" setting. Moreover, this result also prevails in a risky environment where the probability of not benefiting from the public good is publicly known (Dickinson, 1998; Gangadharan and Nemes, 2009).

Other implementations of environmental risk yield mixed conclusions. Like our study, these experiments usually compare standard design with its non-standard equivalent

[7] This finding complements an earlier result from Isaac and Walker (1988b) that higher MPCR induces higher contributions in a standard VCM setting.

in which MPCR is a realization of a mean-preserving-spread lottery. Studies by Levati et al. (2009); Levati and Morone (2013) suggest that there might be a large and negative effect of what we call a homogeneous environmental risk (i.e., MPCR is randomly determined for all group members) on cooperation, but its occurrence depends on the way in which the MPCR lottery is calibrated. In Levati et al. (2009), the risky version of VCM is a social dilemma solely in expected terms: conditional on the realization of the MPCR, it is either individually and socially efficient to contribute nothing (if MPCR is low), or individually and socially efficient to contribute the whole endowment (if MPCR is high). They report a negative effect of environmental risk on cooperation. In Levati and Morone (2013), in turn, the risky environment preserves the social dilemma nature of VCM regardless of the realization of MPCR. In this context, moving from the standard setting to environmental risk to environmental uncertainty (by making the probabilities unknown to players) does not affect cooperation. Similar phenomenon has been recently documented by Björk et al. (2016) in both one-shot and repeated games. On the other hand, a lab-in-the-field experiment conducted in small rural communities by Cárdenas et al. (2017) reveals a negative effect of what we call heterogeneous risk (i.e., each player's MPCR is random and independently determined) on cooperation. Finally, Fischbacher et al. (2014) introduce another type of environmental risk by allowing MPCR to vary within a group according to a publicly known distribution. Hence, the environmental risk in their experiment is competitive: the misfortune of some means benefits to others. In their one-shot, strategy-method VCM setting they observe that this form of environmental risk has a negative effect on both conditional and unconditional contributions.[8]

2.2.1 Our study

Altogether, we draw the following conclusions from these accumulated findings. First, deviating from the "gold standard" design may, if anything, have a negative effect on

[8] Other related studies include Stoddard (2013); Stoddard et al. (2014); Dannenberg et al. (2015); Vesely and Wengström (2017).

cooperation, regardless of whether such deviation is due to environmental uncertainty or environmental risk. However, given that this literature is relatively small and dispersed, it seems well-founded to call for a systematic replication of the existing findings and an exploration of new non-standard VCM settings. Second, the existing findings are quite mixed and it remains unclear why negative effects arise in some particular decision-making contexts (for instance, heterogeneous environmental risk, or competitive environmental risk) but not in others (for instance, homogeneous environmental risk). This, in turn, calls for a tighter control of the channels through which such behavioral differences may arise. Our experiment is designed to serve both of these purposes. We build on, and extend, the study of Fischbacher et al. (2014). Like them, we study the effect of environmental risk in a 4-person VCM game and use their calibration of deterministic and risky MPCR. However, there are two important features that distinguish our study from theirs: the nature of environmental risk (which is competitive in their setting, and non-competitive in ours), and the design of experimental measurements.

Our experiment varies the level at which the environmental risk arises: it can be either agent-specific (heterogeneous risk treatment) or group-specific (homogeneous risk treatment). Thus, unlike Fischbacher et al. (2014), we focus on non-competitive forms of environmental risk: the realizations of risky MPCR within a group of players can be either perfectly correlated, or perfectly independent. As documented by previous economic experiments, whether environmental risk is competitive or not may have behavioral consequences. In a recent article, Krawczyk and Le Lec (2010) study competitive and non-competitive (anologous to our heterougeneous risk) environmental risk in the dictator game. They report that people tend to be less selfish if the realization of outcomes comes under a non-competitive risk; however, both types of risk decrease transfers as compared to the standard, deterministic dictator game.[9] Thus, our variation of the experimental setup used by Fischbacher et al. (2014) is informative for the experimental research on the provision of public goods and, even more generally, on social

[9] See also Brock et al. (2013); Krawczyk and Lec (2016).

interactions under environmental risk. We discuss the implications of our study for this recent strand of economic literature in the concluding section of the paper.

Our theoretical analysis (presented in Section 2.3.3) builds on the intuition that although the expected payoffs (conditional on a given set of group members' contributions) are identical across all experimental conditions (which makes them equivalent in terms of procedural fairness), different treatments may affect the expected payoff inequalities (and thus differ in terms of distributive fairness). Following this intuition, we draw upon the classic model of inequality aversion by Bolton and Ockenfels (2000) and establish the following prediction: homogeneous risk may foster cooperation relative to heterogenous risk, while cooperation levels in the riskless baseline condition should be bounded by those observed in our two environmental risk treatments.

We empirically test our research hypothesis using a controlled lab setting which differs from the one used by Fischbacher et al. (2014) in several ways. They use a within-subject design and elicit players' conditional contributions to the public good, as well as their unconditional one-shot contributions, in a series of VCM games. Our experimental treatments are implemented in a between-subject manner. Like Fischbacher et al. (2014), we observe conditional and unconditional decisions in a static setting. Moreover, following Fischbacher et al. (2012), we enrich this design by adding belief elicitation and a finitely repeated VCM interaction. This refinement allows us to measure how individual beliefs are formed, to establish their link with behavior, and to trace the evolution of cooperation under various environmental risks. To enhance the experimental control, we also collect background information on risk preferences and other-regarding preferences in our experimental sample.

2.3 Experimental design

2.3.1 Voluntary Contribution Mechanism

In the classic voluntary contribution mechanisms, a group of N individuals (each endowed with a certain number of tokens e on their private accounts) funds the public good in the following manner. Each individual privately decides on his level of contribution to the public good c (with $c \leq e$) and keeps any tokens which have not been contributed. The public good is defined as a sum of individual contributions, and the marginal per capita return from the public good is $\alpha < 1$. Thus, the payoff of the individual i in this game (denoted π_i) is given as:

$$\pi_i = e_i - c_i + \alpha \times \sum_{j=1}^{N} c_j \tag{2.1}$$

In this experiment, we are interested in two classic cases: one in which the game is played once, and another in which it is finitely repeated (so that the number of repetitions is public knowledge) in constant groups. In both cases, standard theory (which assumes that all players are self-interested payoff maximizers) suggests that having $\frac{1}{N} < \alpha < 1$ generates a social dilemma. Although the group welfare is maximized when all players make full contributions, the dominant strategy of each individual is to contribute nothing (which leads to the unique Nash equilibrium in a one-shot game, and the subgame perfect Nash equilibrium in a finitely repeated game).

Following the standard design used in numerous VCM experiments, in our baseline condition the value of α is deterministic, homogeneous and publicly known. In our environmental risk treatments (either homogeneous - HomR, or heterogeneous - HetR), MPCR is generated through a mean-preserving lottery. Both α_{HomR} and α_{HetR} are drawn from a binary set $\{\underline{\alpha}, \bar{\alpha}\}$ such that $Pr(\underline{\alpha}) = Pr(\bar{\alpha}) = 0.5$ and $E(\alpha_{HomR}) = E(\alpha_{HetR}) = \alpha$. The rules of this lottery are public knowledge, but its outcome remains unknown in the decision-making stage of the game. Thus, the timing of the events is as follows: first, each player decides about his contribution to the public good; then, the lottery determines his MPCR. The key difference between the two treatments is that α_{HomR} is being drawn for the entire group, whereas α_{HetR} is being drawn independently for each group member. Finally, we set $\frac{1}{N} < \underline{\alpha} < \alpha < \bar{\alpha} < 1$ which guarantees that the social dilemma nature of the game is maintained for all the possible values of MPCR, so that the standard predictions extend to the game played under environmental risk.

2.3.2 Calibration of the experimental games

In the laboratory experiment, players form groups of four. Each player is endowed with 10 Experimental Currency Units (ECU) which he allocates (in integer values) between his private account and the public good. In the baseline treatment, each ECU invested in the public good yields the return of 0.4 ECU to every player (which is public knowledge). In the HomR and HetR treatments, each ECU invested in the public good yields either 0.3 ECU or 0.5 ECU to each player, both outcomes being equally likely. Such calibration of the MPCR lottery is based on the study by Fischbacher et al. (2014) who observe a negative effect of random MPCR on contributions.[10] We also note that, in the light of the previous experiments, the size of the spread between the different realizations of random MPCR does not seem to drive *per se* the observed behavior. For instance, Levati and Morone (2013) and Björk et al. (2016) report a null result based on a larger spread than the one adopted herein (0.6 vs. 0.9, and 0.3 vs. 0.9, respectively; MPCR in the riskless condition is always mean-preserving). Boulu-Reshef et al. (2017) also report a null result based on an experiment in which MPCR is drawn from a continuous uniform distribution ranging from 0.3 to 0.75. However, it does matter whether calibration of the MPCR lottery is such that the social dilemma nature of the game is maintained for any realization or not. Levati et al. (2009); Levati and Morone (2013) jointly report lower contributions to the public good in a game in which the social dilemma only occurs in expectancy, but the dominant strategy may switch from null to full contribution depending on the realization of MPCR (0.4 vs. 1.1).

2.3.3 Theoretical prediction

In this section, we establish a theoretical prediction for our experimental games. We would like to emphasize that the existing literature lacks a common consensus on how

[10] In a set of within-subject, strategy-method treatments with fixed MPCR (either 0.3 with group heterogeneity, 0.4 without group heterogeneity, or 0.5 with group heterogeneity), they show that lower (higher) returns induce a significant decrease (a weakly significant increase) of contributions when MPCR is heterogeneous. Thus, their data suggest that the positive effect of the value of the MPCR (previously documented by Isaac and Walker, 1988b) may interact with the negative effect of heterogeneous (and competitive) MPCR.

to model strategic choices in social dilemmas with environmental risk. Previously, researchers have applied either models solely based on risk preferences (e.g. Levati et al., 2009), or (like we do here) on other-regarding preferences (e.g. Fischbacher et al., 2014). As pointed out in a recent study by (Cettolin et al., 2017, p. 97), the existing theoretical developments fall short of combining risk preferences and other-regarding preferences in a canonical way.

Furthermore, Saito (2013) studies distributive (and thus non-strategic) choices under environmental risk and builds a model based on two criteria: the *ex ante* equality of opportunities (procedural fairness), and the *ex post* equality of outcomes (distributive fairness).[11] Saito's theory is further supported by the experiment by Krawczyk and Le Lec (2010). Our experiment has been designed to mute any concerns for procedural fairness: given the linearity of the VCM payoff function, and since the MPCR lotteries in both HetR and HomR are mean-preserving as compared to the baseline treatment, an agent's expected payoff is constant across all conditions for any given set of group contributions. However, distributive fairness concerns may still be important, since random realizations of MPCR may affect the distribution of agents' payoffs on top of their contributions to the public good. *Ceteris paribus*, different forms of environmental risk may differently affect the *ex post* inequalities in the final distribution of payoffs. Following this intuition, we build a model to address the following question: how does the behavior of an expected utility maximizer with inequality concerns vary across our three experimental conditions?

We nest our analysis in the classic model of inequality aversion by Bolton and Ockenfels (2000). This approach enables us to address our question in a traceable manner within a standard behavioral model, and to generate a testable prediction for our experiment. Our approach has two main advantages. First, it is parsimonious: other-regarding concerns are captured by a single parameter in the utility function. Second, its behavioral

[11]See also related studies by Bolton et al. (2005); Trautmann (2009); Krawczyk (2011). To capture other-regarding preferences, those studies commonly apply different theories of inequality aversion: either Fehr and Schmidt (1999) or Bolton and Ockenfels (2000). In this study, we opted for the latter. See also Rabin (1993); Charness and Rabin (2002); Falk and Fischbacher (2006) for alternative theories of other-regarding preferences.

prediction meshes well with the existing empirical data on cooperation under different types of environmental risk. Although our experiment offers the first direct investigation of cooperation under different environmental risks, an indirect inference from the existing data suggests that HomR may yield higher contribution levels than HetR. Recent results from Levati and Morone (2013); Björk et al. (2016); Cárdenas et al. (2017) jointly suggest that homogeneous (hetereogeneous) risk does not change contributions (undercuts contributions) as compared to the standard VCM game (see Section 2.2).

In the general framework of the Equity, Reciprocity and Competition (ERC) theory proposed by Bolton and Ockenfels (2000), decisions are driven by personal payoff maximization and an aversion to inequality. Agent i's utility function in an N-person game is:

$$U_i = U_i\left(p_i, \frac{p_i}{P}\right) \tag{2.2}$$

with p_i denoting agent i's personal payoff, and $P = \sum_{j=1}^{N} p_j$ is the sum of all players' payoffs. This function is such that, *ceteris paribus*, agent's utility increases in the first parameter (own payoff), and decreases symmetrically as the value of the second parameter (relative standing) moves away from the reference value of $\frac{1}{N}$; see their paper for a complete discussion of the analytical assumptions and properties of this utility function. Building on Bolton and Ockenfels (2000), Fischbacher et al. (2014) propose the following additively separable form of the utility function (2.2) in the context of a 4-person VCM game:

$$U_i(\pi_i) = \pi_i - \nu_i \times \left(\frac{\pi_i}{\pi_i + \sum_{j \neq i} \pi_j} - \frac{1}{4}\right)^2 \tag{2.3}$$

with π_i and π_j defined as in equation (2.1), and the parameter $\nu_i \geq 0$ measuring the strength of agent's inequality aversion.[12]

[12]For $\nu < 150$, agents behave in a self-interested manner and their best response is to contribute nothing regardless of what others do.

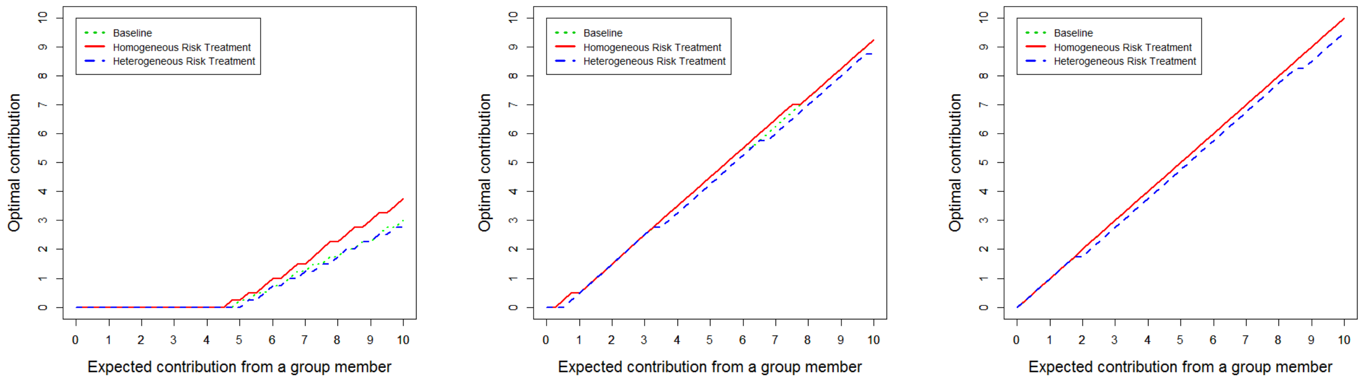
The decision-maker is an expected utility maximizer who furthermore expects each player in his group to contribute an amount $\bar{c}_{-i}$.[13] The utility function (2.3) can be plugged into a simulation exercise that traces an agent's behavior conditional on $\bar{c}_{-i}$ under different forms of environmental risk. For the riskless baseline treatment, we can easily derive a utility maximizer's best response function, i.e. the utility-maximizing contribution level c_i as a function of $\bar{c}_{-i}$. In the HomR treatment, the expected utility maximization must also take into account the randomness of α (either high or low for the whole group, both outcomes are equiprobable). Finally, in the HetR treatment we account for two possible values of the agent's α (either high or low MPCR, with equal probabilities) and all the possible combinations of the other players' α. Further details on this procedure are provided in Appendix A.1.

Figures 2.1a-c present the individual best response functions for different treatments and values of ν_i. This exercise yields several insights. First, we note that for all conditions the best response function converges towards the 45 degree line as ν_i increases. Second, throughout this process of convergence the best responses observed in HomR may be greater than those observed in HetR, although this gap is more pronounced for relatively small values of ν_i (Figure 2.1a) than for the relatively large ones (Figure 2.1c). Finally, the best response function for the riskless baseline condition is bounded by those generated by HetR and HomR conditions. These observations allow us to rank the contribution levels under different experimental conditions so as to state our research hypothesis:

Research hypothesis. *Ceteris paribus*, the contribution levels in the HomR treatment dominate those from the HetR treatment. The contribution levels in the riskless baseline condition are bounded by those observed in the HetR and HomR treatments.

[13]The latter assumption implies that other group members are expected to be of the same "type". It is a simple way to account for the presence of strategic uncertainty due to incomplete information in the game.

Figure 2.1 – Simulated best response functions



(a) $v_i = 250$ (b) $v_i = 2500$ (c) $v_i = 25000$

2.4 Experimental procedures

212 students (49.53% males, average age 21.5) were recruited using hroot (Bock et al., 2014). We had 72 participants (in 18 groups) in both the baseline and the HomR treatments, and 68 participants (in 17 groups) in the HetR treatment. We run a total of 10 experimental sessions in June, September and October 2016 in the GATE-LAB, the experimental laboratory of the GATE Lyon-Saint-Etienne research institute in France. All sessions were computerized using z-Tree (Fischbacher, 2007). The usual length of an experimental session was one hour. In addition, each session was preceded by a series of online tasks that were sent to all the registered participants one week in advance, and had to be completed at least 24 hours before the start of the laboratory session.[14] We chose this method to minimize the contamination between the two sets of observations. The average payoff was 14.70 Euros; this amount includes the gains from online tasks, as well as the payoffs earned in the laboratory experiment.

[14]Out of 251 subjects who registered for the experiment and completed the online questionnaire, 222 showed up for the subsequent session in the lab (out of which 10 could not participate due to session overbooking). Thus, the attrition rate between the two parts is modest – less than 12%.

2.4.1 One week before the experiment: risk preferences and other-regarding preferences

One week before the experimental session, all registered participants received an email with a personal code and a link to two online tasks – the risk preferences test by Gneezy and Potters (1997) and the Social Value Orientation (SVO) Slider Measure by Murphy et al. (2011) – to be completed at least 24 hours before the laboratory session. These tests were followed by an unrelated psychological questionnaire – a 17-item Spitefulness Scale by Marcus et al. (2014) – so as to cloud the expectations that the participants could have formed about the tasks in the experimental session.[15] These tasks were incentivized and presented in random order. All payoffs were expressed in Experimental Currency Units (ECU), with 100 ECU being worth 2.50 Euros. Subjects received no immediate feedback about the outcomes, and were paid for each of them at the end of the experimental session in the laboratory.

In the risk preferences test by Gneezy and Potters (1997), a decision-maker is endowed with 100 ECU, some (or all) of which he can invest in the following lottery: 50% chance of multiplying the investment by the factor of 2.5 times, and 50% chance of losing the invested amount. Any decision-maker who does not invest the whole amount is considered as being risk averse, and the invested amount is used as a measure of risk aversion.[16]

In the Social Value Orientation (SVO) test by Murphy et al. (2011), a decision-maker chooses an allocation of money for himself and for another person amongst 9 possible allocations in 6 different distributional tasks. Then, these choices are transformed into an

[15] Subjects were paid a flat fee of 2 Euros for completing this part. The full questionnaire is provided in the Appendix A.3. For the sake of illustration, one of the questions looks as follows: *If I was one of the last students in a classroom taking an exam and I noticed that the instructor looked impatient, I would be sure to take my time finishing the exam just to irritate him or her.* Participants provided responses for each item using scales ranging from 1 (strongly disagree) to 5 (strongly agree). We find similar distributions of scores (around 20 on average) in all experimental conditions ($p = 0.667$, Kruskal-Wallis test).

[16] A potential shortcoming of this method is that it cannot serve to distinguish between risk-neutral and risk-seeking agents, since both types should invest their whole endowment. However, this does not seem to be a concern in the light of the existing empirical evidence: the fraction of people who invest their whole endowment is fairly small. This is also the case in our experimental sample. See Charness et al. (2013) for a related discussion.

Table 2.1 – Risk preferences and other-regarding preferences across experimental conditions

	Average outcome			
Measure:	Baseline	HetR	HomR	p
Gneezy-Potters test score	56.74	50.90	53.14	0.479 (F-test)
SVO profile:				
Competitive	0	1	0	
Individualistic	39	40	48	0.308 (Fisher's exact test)
Prosocial	33	27	24	

individual score that determines the SVO profile (altruistic, competitive, individualistic, prosocial). We use the original set of distributional tasks (all the amounts are expressed in ECU) and the strategy method to elicit responses in the role of the decision-maker. We collect choices in the role of the decision-maker from all the participants. We also inform them that they will be randomly and anonymously matched in pairs at the end of the experiment, that in each pair one person will be randomly chosen as the decision-maker, and that both players' payoffs from this task will correspond to the decision-maker's choice in a randomly selected task.

Based on our measures of risk preferences and other-regarding preferences, we find that participants are properly randomized with respect to both characteristics.[17]

2.4.2 Experimental session: VCM games

The *in situ* stage of the experiment consists of two parts. In each part, we implement a 4-player VCM game, and groups remain constant throughout the experiment (all of which is public knowledge). We use neutral framing: each player can invest a certain amount in a common group project. The common procedures for each part are as follows. The participants are informed that there there will be two parts of the experiment, and paper instructions are distributed and read aloud at the beginning of each part (such that the participants are unaware of the content of part 2 while acting in part 1).[18] In the baseline

[17] Additional non-parametric results are provided in the Appendix A.5.
[18] These instructions, translated from French to English, are provided in the Appendix A.2.

treatment, subjects are also provided with a table that summarizes the individual payoff generated through different combinations of personal and group contributions. In each of the risk treatment, a separate table is provided for both possible values of MPCR. Finally, the participants are asked to take a short quiz of comprehension. After answering any remaining questions, the experimental game begins.

In the first part of the experiment, subjects are endowed with 10 ECU (equivalent of 3 Euros) and their contribution may be any integer value between 0 and 10 ECU. They play the following one-shot VCM game. First, they are asked to make one unconditional contribution without knowing anything about other players' behavior. Then, they provide eleven consecutive conditional contributions, each of them being a response to a possible value of the average contribution from the other group members (which are also integers between 0 and 10 ECU). Following the classic experiment by Fischbacher et al. (2001), the rules of the one-shot game guarantee that all choices are incentivized. At the end of the game, one player is selected at random. For the non-selected players, we take into account their unconditional contributions. For the selected player, we take into account his conditional contribution that corresponds to the average unconditional contribution of the remaining players. Then, we also elicit each players' beliefs about the average contribution to the public good of the remaining group members: they can earn 5 ECU for a correct guess (with a 1 ECU margin of error). No feedback (either on the outcome of the MPCR lottery or about other players' behavior) is provided at that point in order to avoid contamination of observations in the second part.[19]

In the second part of the experiment, subjects play a VCM game for 10 rounds in constant groups that have not changed since the previous part (all of which is public knowledge). The renewable endowment in each round is 10 ECU. We provide round-to-round feedback on the individual contribution, the sum of all group members' contributions, the

[19]Both parts of the experiment are always presented in the same order. Fischbacher et al. (2012) report an absence of order effects in such design.

individual return from the group project, the individual return from the private account, and the individual gain. [20] One round is drawn for payoff at the end of the experiment.

2.5 Results

In this section, we summarize our main empirical results from the one-shot and finitely repeated VCM games. Altogether, we find very limited support for the research hypothesis put forth in Section 2.3.3. All outcomes remain fairly stable across our experimental conditions, and echo the standard patterns of behavior previously documented in numerous experiments using the standard VCM setting.

2.5.1 Conditional and unconditional contributions in the one-shot VCM

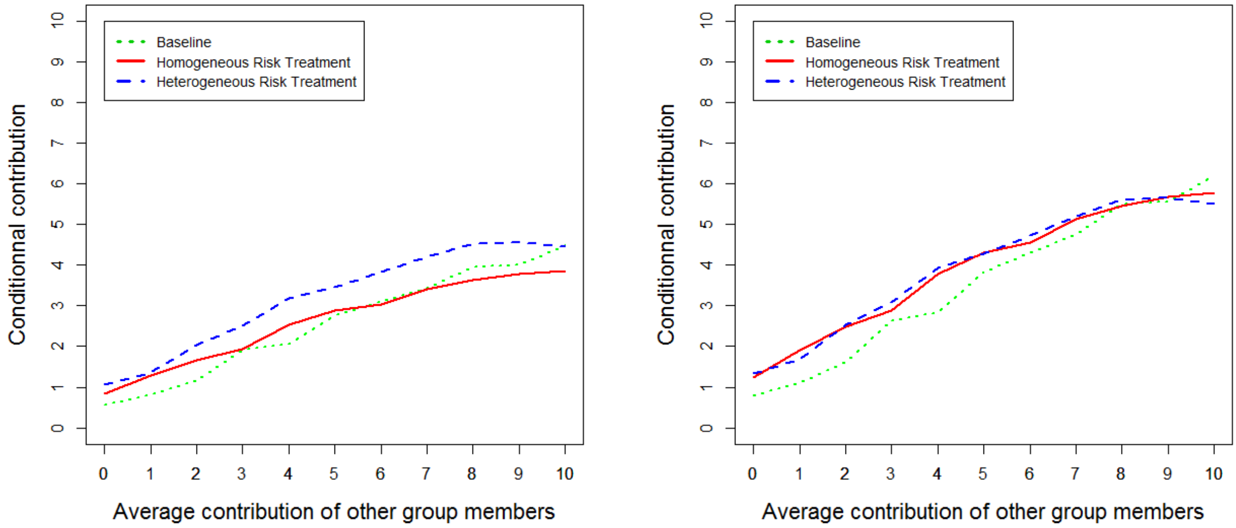
Result 1. The patterns of conditional contributions do not vary significantly across our three experimental conditions.

Support. Figure 2.2a summarizes the patterns of average conditional contributions in our experimental treatments. In all three treatments, conditional contributions follow a standard pattern: they tend to increase in the value of the other group members' average contribution, but are far from reaching it. Moreover, F-test does not reject the null hypothesis that the average conditional contributions are the same in all three treatments for almost every value of other group members' average contribution. The sole exceptions are the values of 2 ($p = 0.048$) and 4 ($p = 0.031$); however, these results do not survive the Bonferroni correction for multiple comparisons. Therefore, we conclude that conditional contributions do not vary significantly across our treatments.[21]

[20] An alternative design would consist in revealing how other group members benefited from the common project in every round. This feature seems relevant for the HetR condition (in which MPCR may vary within a group), but not for the HomR condition (in which MPCR is constant within a group). Here, we opted for providing no information about other players' benefits from the common project. The main reason behind this design choice is the external validity argument put forth in the opening section of the paper – as we believe, in real life it is unlikely that one perfectly observes how other people benefit from a public good.

[21] Additional non-parametric results are provided in the Appendix A.6.

Figure 2.2 – Distribution of players according to their actions



(a) Whole sample (b) Free-riders excluded

Furthermore, in all treatments we find a similar scope of pure free-riding (that is, contributing zero regardless of what others do): 27.78% in the baseline treatment, 19.12% in HetR and 33.33% in HomR. χ^2 test does not reject the null hypothesis that these outcomes come from the same distribution ($p = 0.162$). The mean conditional contribution curves after excluding those players (Figure 2.2b) remain similar across our three experimental conditions.[22] ■

Result 2. Neither the unconditional contributions, nor the beliefs about other players' behavior, nor the correlation between these two outcomes vary significantly across our experimental conditions.

[22]Once again, we do not detect any significant differences between the mean outcomes observed in the three treatments. The mean conditional contribution associated with the other group members' average contribution of 2 and 4 are (weakly) significantly different ($p = 0.058$ and $p = 0.037$, respectively), but these results do not survive the application of the Bonferroni correction.

Support. Table 2.2 summarizes the average unconditional contributions and the beliefs about other players' behavior in each experimental treatment. F-test does not reject the null hypothesis that the average unconditional contributions are the same in all experimental conditions. We report the same outcome when testing for the symmetry of beliefs across treatments. Furthermore, in a series of pairwise between-treatment comparisons based on two-sided t-tests we do not reject the null hypothesis of equal means either for unconditional contributions or for beliefs, with all $p \geq 0.232$. Nonparametric ranksum tests point to similar conclusions. At this point, it seems important to discuss a limitation of our analysis related to its statistical power. Upon a visual inspection, most differences observed across our experimental conditions are not pronounced in purely economic terms, and the effect sizes (measured by Cohen's d, that is the difference between two means divided by the standard deviation calculated from the sample) observed in our data are small (0.2 or less). For our sample size of around 70 subjects per treatment (which is commonplace in economic experiments run in the lab), attaining the reference power of 0.8 (and the significance level of 0.05) would require at least a medium ($d = 0.5$) effect size. In addition, a *post hoc* power analysis suggests that achieving a statistical power of 0.8 (and the significance level of 0.05) for $d = 0.2$ would require extremely large samples (400 subjects per treatment) that are not feasible in our standard laboratory setting. For these reasons, like many other null results observed in the lab, ours should be taken with caution. Finally, in all treatments we find a strong and positive correlation between unconditional contributions and beliefs: all correlation coefficients are found to be statistically significant at the 1% level. Jennrich's test for a joint equality of the three correlation coefficients yields $p = 0.117$. Additional non-parametric results are provided in the Appendix A.7. ■

Our Result 2 echoes the previous findings from VCM experiments (see, for instance, Weimann, 1994; Croson, 1996; Neugebauer et al., 2009; Fischbacher and Gächter, 2010) that (i) the beliefs about others' contributions tend to be above the individual contribution levels, and that (ii) these two variables are positively correlated. Importantly, neither the data on conditional contributions presented in Figures 2.2a and b, nor the

Table 2.2 – Unconditional contributions and beliefs across experimental conditions

	Average			
Measure:	Baseline	HetR	HomR	p
Unconditional contribution	3.60	4.06	4.26	0.445
Beliefs about others	4.40	4.74	4.48	0.584
Pearson's r	0.448	0.557	0.684	0.117

Note. p-values correspond to F-test for the equality of means scores (lines 1 and 2), or to Jennrich's test for correlation coefficients (line 3; all coefficients are significantly different from zero at the 1% level).

data on unconditional contributions summarized in Table 2.2, corroborate the direction of treatment effects outlined in the research hypothesis in Section 2.3.3.

In addition, regression models summarized in Table 2.3 investigate the link between the outcomes reported in Table 2.2 and the individual characteristics reported in Section 2.4.1. Individual characteristics are described by two variables, $1[Prosocial]$ (either prosocial or not, based on the SVO slider measure), and GP score (the Gneezy-Potters test score). We estimate two sets of linear regression models, separately for each of the experimental conditions. In the first set of models, we regress the dependent variable of interest – either one's beliefs about other group members' average contribution to the public good (models M1-M3), or one's unconditional contribution (M4-M6) – on the explanatory variables described above. In the second set of models (M7-M9), we take one's unconditional contribution as dependent variable, and include one's beliefs about other group members' average contribution to the public good as an explanatory variable, alongside the individual characteristics dummies. Two main results prevail across all conditions. First, individual characteristics related to other-regarded preferences and risk preferences play a marginal role in explaining the variation in unconditional contributions or the variation in beliefs about other players' contributions to the public good. Second, the beliefs one holds about other people's behavior are an important predictor of individual contributions (echoing the data reported in Table 2.2) once we control for individual characteristics.

Table 2.3 – Unconditional contributions, beliefs and individual characteristics: regression analysis

Dep. variable:	Beliefs			Unconditional contribution					
Model:	M1	M2	M3	M4	M5	M6	M7	M8	M9
Treatment:	Base	HetR	HomR	Base	HetR	HomR	Base	HetR	HomR
Intercept	4.364^a	3.733^a	4.305^a	2.049^b	2.644^a	3.060^a	-1.319	-0.367	-1.811^b
	(0.519)	(0.534)	(0.566)	(0.871)	(0.814)	(0.915)	(1.108)	(0.921)	(0.894)
Beliefs	—	—	—	—	—	—	0.772^a	0.807^a	1.132^a
							(0.181)	(0.162)	(0.140)
$1[Prosocial]$	-0.014	0.320	-0.025	1.077	0.337	1.540^c	1.087	0.080	1.569^b
	(0.435)	(0.474)	(0.538)	(0.731)	(0.722)	(0.870)	(0.654)	(0.619)	(0.626)
GP score	0.001	0.017^c	0.004	0.019	0.025^c	0.013	0.018	0.011	0.009
	(0.007)	(0.009)	(0.009)	(0.012)	(0.013)	(0.014)	(0.011)	(0.012)	(0.010)
N	72	68	72	72	68	72	72	68	72
R^2	0.000	0.063	0.003	0.058	0.056	0.052	0.257	0.320	0.515
$Prob > F$	0.993	0.121	0.916	0.128	0.160	0.160	0.000	0.000	0.000

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. Dependent variables are: player's beliefs about other group members' average contribution to the public good (M1-M3), and player's unconditional contribution to the public good (M4-M9). In all the models, the set of explanatory variables includes individual characteristics: $1[Prosocial]$ (dummy variable set to 1 if an individual's type in the SVO task is prosocial, and 0 otherwise), and the Gneezy-Potters test score (GP score). In addition, models M7-M9 also include individual's beliefs about other group members' average contribution to the public good as an independent variable.

2.5.2 Cooperation in the repeated VCM

So far, we have presented systematic evidence suggesting that the environmental risk does not affect the patterns of contributions observed in the static VCM. In this part, we turn to an investigation of the effects of environmental risk in the dynamic setting of a finitely repeated VCM.

Result 3. Players' choices in the first round of the repeated VCM game are consistent with their unconditional contributions in the static VCM game.

Support. For all treatments, two-sided paired t-test does not reject the null hypothesis that the mean difference between the two contributions equals zero. The results are as follows. Baseline treatment: mean unconditional one-shot contribution of 3.60 vs. mean round 1 contribution of 3.60 ($p = 1.000$); HetR: 4.06 vs. 3.81 ($p = 0.534$); HomR: 4.26 vs. 4.44 ($p = 0.634$).[23] ■

[23]Non-parametric signed-rank test yields consistent results.

Figure 2.3 – Dynamics of cooperation across treatments: mean contributions

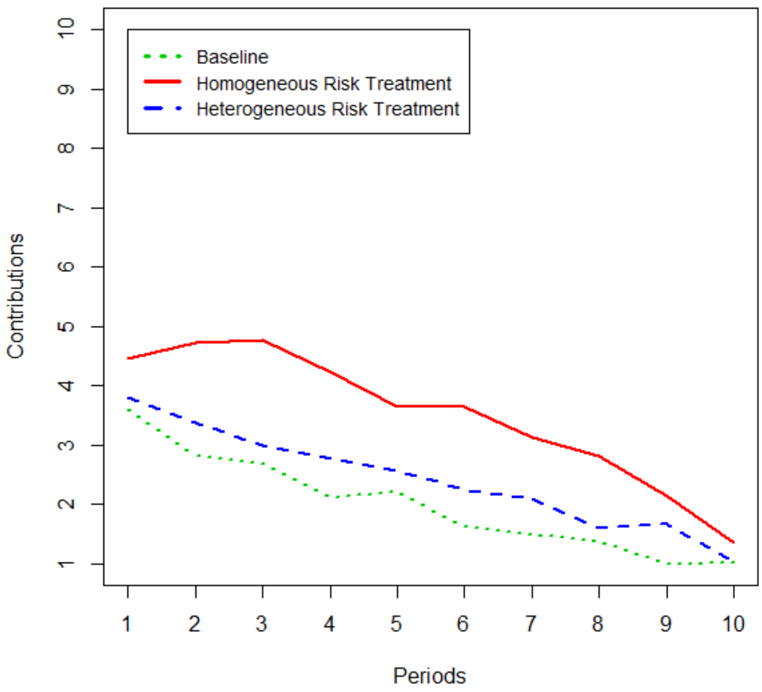


Figure 2.3 depicts the dynamics of mean contributions in the repeated VCM games. Once again, we observe standard patterns of behavior. In all three treatments, the initial contributions are relatively high (around 40% of the endowment on average), and then collapse, reaching similar levels (around 10% of the endowment on average) in the final (tenth) round of the game. The curves from the baseline treatment and the HetR treatment have similar slopes and run closely to each other in a standard manner. In both cases, we observe a steady fall of contributions over time. The evolution of cooperation in the HomR treatment is slightly different: players manage to maintain cooperation in the first three rounds of the game, but then it collapses exactly as in the remaining treatments. Due to this early-stage gap, the average contribution in that treatment is found to be higher than elsewhere. Importantly, this effect nicely meshes with our initial research hypothesis. However, we remain cautious about this result and do not overstate

its magnitude, given that it only stems from an early and fugitive deviation from the usual dynamics of cooperation.

Below, we summarize these findings and provide their statistical support. The statistical analysis is based on the regression models presented in Table 2.4.[24] In models M1-M3, we regress individual contributions on treatment dummies (one for HomR and one for HetR) using different sets of observations: round 1 observations (M1), round 10 observations (M2), or all observations (M3). Model M4 extends M3 by additionally incorporating round dummies (representing rounds 2-3, 4-5, 6-7, 8-9, and 10) as well as their interactions with the treatment dummies. To account for the potential within-group correlation of observations due to repeated interactions, the residuals are clustered at the group level in models M2-M4 (there are 53 clusters in total).[25] Moreover, the delete-one-jackknife resampling procedure is applied to estimate standard errors so as to account for the potential small sample bias.[26]

Result 4. We find no differences across treatments either in the first round or in the final round average contributions in the repeated VCM game.

Support. This result stems from the regression models M1 and M2 summarized in the first two columns of Table 2.4. In both models, treatment dummies are neither individually nor jointly significant at the conventional level of 5%. ■

Result 5. The overall average contribution is higher in the HomR treatment than in the remaining experimental conditions. However, this difference is mostly driven by a transient variation at an early stage of the game: players in the HomR treatment

[24] Additional non-parametric results are provided in the Appendix A.8 and A.9. Furthermore, double-censored tobit regressions yield equivalent results. These additional estimates are provided in the Appendix A.10.

[25] In the context of session effects in the lab, Fréchette (2012) notes that repetition may give rise to dynamic effects the form of which is unknown to the experimenter, and suggests clustering of residuals as a possible remedy against the resulting misspecification of the variance-covariance matrix in a regression model.

[26] Jacquemet and Zylbersztejn (2014) provide a detailed description of the econometric procedure used in our analysis.

Table 2.4 – The patterns of cooperation over time and across treatments: regression analysis

	Dep. variable: contribution in round t			
Model:	M1	M2	M3	M4
Observations:	$t=1$	$t=10$	$t \in [1;10]$	$t \in [1;10]$
Intercept (β_0)	3.597[a]	1.014[a]	1.989[a]	3.597[a]
	(0.376)	(0.325)	(0.275)	(0.342)
$1[HomR]$ (β_1)	0.847	0.347	1.497[a]	0.847
	(0.532)	(0.518)	(0.519)	(0.528)
$1[HetR]$ (β_2)	0.212	0.016	0.429	0.212
	(0.540)	(0.477)	(0.398)	(0.438)
$1[round2-3]$ (β_3)				-0.861[b]
				(0.356)
$1[round4-5]$ (β_4)				-1.431[a]
				(0.355)
$1[round6-7]$ (β_5)				-2.049[a]
				(0.374)
$1[round8-9]$ (β_6)				-2.410[a]
				(0.399)
$1[round10]$ (β_7)				-2.583[a]
				(0.437)
$1[round2-3] \times 1[HomR]$ (β_8)				1.160[b]
				(0.480)
$1[round4-5] \times 1[HomR]$ (β_9)				0.917
				(0.636)
$1[round6-7] \times 1[HomR]$ (β_{10})				0.986
				(0.690)
$1[round8-9] \times 1[HomR]$ (β_{11})				0.438
				(0.684)
$1[round10] \times 1[HomR]$ (β_{12})				-0.500
				(0.681)
$1[round2-3] \times 1[HetR]$ (β_{13})				0.243
				(0.446)
$1[round4-5] \times 1[HetR]$ (β_{14})				0.291
				(0.498)
$1[round6-7] \times 1[HetR]$ (β_{15})				0.416
				(0.538)
$1[round8-9] \times 1[HetR]$ (β_{16})				0.233
				(0.519)
$1[round10] \times 1[HetR]$ (β_{17})				-0.196
				(0.534)
N	212	212	2120	2120
R^2	0.013	0.004	0.041	0.122
$Prob > F$	0.256	0.769	0.021	0.000

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. In all models, the set of explanatory variables includes treatment dummies. In M4, it also includes (pairwise) round dummies and their interactions with treatment dummies. In M2-M4, residuals are clustered at the group level (53 clusters), standard errors are computed using the leave-one-out jackknife procedure.

manage to maintain cooperation in the first three rounds of the game, while the decay of cooperation is triggered instantaneously in other conditions.

Support. This result stems from the regression models M3 and M4 summarized in columns 3 and 4 of Table 2.4. Model M3 suggests that the aggregate average contribution in HomR is significantly different than in the baseline treatment ($p = 0.006$) and in the HetR treatment ($p = 0.047$). However, model M4 indicates that these differences are mainly driven by different dynamics in rounds 1 to 3. First, the model confirms that contributions in the baseline treatment decrease over time in a monotone way: the coefficients β_3 to β_7 are all significant and we strongly reject the null hypothesis of their equality ($p < 0.001$). The insignificance of coefficients β_{13} to β_{17}, in turn, suggests that this pattern is preserved in the HetR treatment. However, the same cannot be said about the HomR treatment. The significance and the size of coefficient β_8, coupled with the insignificance of coefficients β_9 to β_{12}, points to the conclusion that the treatment effect reported in model M3 is merely due to the fact that the decay of cooperation in the HomR treatment is delayed by two rounds relative to the baseline and HetR treatment.[27]
■

2.5.3 Past randomness and present behavior

In the last set of regressions, we investigate the link between the exposure to random realizations of MPCR in the past and present contribution decisions. Clearly, a rational decision-maker should not condition his future choices on any random outcomes observed in the past. However, an important body of behavioral research has documented that in many contexts (such as lotteries or sports betting) people may misperceive ran-

[27]One might suspect that this short-lived bloom of cooperation in HomR may be driven by "lucky" outcomes of the MPCR lottery. However, descriptive statistics from rounds 1 and 2 do not support the hypothesis that "lucky" groups feel more encouraged to cooperate than the "unlucky" ones. To see this, let us compare the evolution of contributions between rounds 1 and 2 in those groups that experienced $\bar{\alpha}$ in $t = 1$ (12 groups, 48 subjects) with those that experienced $\underline{\alpha}$ in $t = 1$ (6 groups, 24 subjects). Not surprisingly, in both groups we observe similar average contributions in $t = 1$ (4.563 and 4.208, respectively) in which decisions are made before the first MPCR lottery takes place. Then, these contribution levels are maintained in $t = 2$ regardless of the the value of α drawn for those groups in the previous round (4.958 and 4.250, respectively). Therefore, groups do not seem to condition their behavior in $t = 2$ on the realization of α in $t = 1$. Related evidence is provided in Table 2.5.

domness and make biased choices, for instance by following the "law of small numbers" (see Rabin, 2002). In this part, we argue that our results are not driven by this kind of misperception of randomness in the game. This evidence is summarized in Table 2.5.

For each treatment, we estimate a regression model that explains individual contribution at time t with the following set of variables. To integrate information about one's past experience with random MPCR, in models M1 and M3 we include a dummy variable indicating whether the realization MPCR in $t-1$ was high ($1[\bar{\alpha}_{t-1}] = 1$) or low ($1[\bar{\alpha}_{t-1}] = 0$). Then, in models M2 and M4 we also take into account the relative frequency of high MPCR in all rounds preceding $t-1$ (variable $Freq(\bar{\alpha})_{(1;t-2)}$), as well as an interaction between these two variables. Finally, we account for the general decay of contributions over time by adding round dummies, as well as individual characteristics: $1[Prosocial]$ (SVO profile, either prosocial or not) and GP score (the Gneezy-Potters test score). These models are estimated separately for each of the environmental risk treatments using the econometric procedure outlined in the previous section. The results of this exercise are presented in Table 2.5. Across all the models, none of the coefficients γ_1 to γ_3 is found to be significant at the conventional level of 5%. This suggests that players' decisions are not biased by the past realizations of random MPCR. These models also yield some (yet limited) evidence on the role of individual characteristics in a repeated game played under environmental risk. Models M1 and M2 suggest that players with prosocial profile in the SVO slider measure tend to contribute significantly more than others under heterogeneous risk. However, as shown in models M3 and M4, this result does not extend to the homogeneous risk treatment. Furthermore, our econometric exercise detects no effect of differences in risk aversion on contributions in either treatment.[28]

[28]The estimates from an analogous exercise performed on the data from the repeated baseline game (hence excluding the variables related to the coefficients γ_1 to γ_3) is provided in the Appendix A.11. Controlling for a negative time trend, our regression analysis suggests that players with $1[Prosocial] = 1$ on average tend to contribute significantly more than others ($p = 0.043$). However, a robustness check based on a double-censored tobit regression only points to a weak (10% level) statistical significance of this outcome ($p = 0.057$). Like elsewhere, we also report that the Gneezy-Potters test score does not happen to be a statistically significant predictor of players' behavior.

Table 2.5 – Present contributions and random MPCR in the past: regression analysis

	Dep. variable: contribution in round t			
Model:	M1	M2	M3	M4
Treatment:	HetR	HetR	HomR	HomR
Intercept (γ_0)	2.441^a	1.954^a	4.064^a	3.823^b
	(0.390)	(0.662)	(0.872)	(1.417)
$1[\bar{\alpha}_{t-1}]$ (γ_1)	0.236	0.147	-0.246	-0.557
	(0.195)	(0.440)	(0.517)	(0.779)
$Freq(\bar{\alpha})_{(1;t-2)}$ (γ_2)	—	0.156	—	0.603
		(0.667)		(1.371)
$1[\bar{\alpha}_{t-1}] \times Freq(\bar{\alpha})_{(1;t-2)}$ (γ_3)	—	0.395	—	0.232
		(0.847)		(1.673)
Round (dummy variables):				
3 (γ_4)	-0.389	–	0.001	–
	(0.352)		(0.380)	
4 (γ_5)	-0.611^c	-0.214	-0.514	-0.442
	(0.344)	(0.309)	(0.468)	(0.440)
5 (γ_6)	-0.809^b	-0.418	-1.124^c	-1.085^c
	(0.382)	(0.290)	(0.556)	(0.590)
6 (γ_7)	-1.101^b	-0.697	-1.152^b	-1.106^c
	(0.429)	(0.447)	(0.496)	(0.603)
7 (γ_8)	-1.293^b	-0.898^c	-1.666^a	-1.602^b
	(0.493)	(0.491)	(0.539)	(0.703)
8 (γ_9)	-1.762^a	-1.359^a	-1.971^a	-1.869^b
	(0.509)	(0.467)	(0.482)	(0.650)
9 (γ_{10})	-1.703^a	-1.292^a	-2.624^a	-2.510^a
	(0.384)	(0.261)	(0.570)	(0.782)
10 (γ_{11})	-2.346^a	-1.941^a	-3.406^a	-3.295^a
	(0.361)	(0.270)	(0.537)	(0.748)
$1[Prosocial]$ (γ_{12})	1.656^a	1.562^a	0.887	0.870
	(0.359)	(0.393)	(0.804)	(0.820)
GP score (γ_{13})	0.003	0.003	0.010	0.008
	(0.005)	(0.005)	(0.008)	(0.008)
N	612	544	648	576
R^2	0.155	0.142	0.111	0.108
$Prob > F$	0.000	0.000	0.000	0.001

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. Observations come from rounds 2-10 in M1 and M3, and from rounds 3-10 in M2 and M4. Residuals are clustered at the group level (17 clusters in HetR, 18 clusters in HomR), standard errors are computed using the leave-one-out jackknife procedure.

2.6 Concluding remarks

This paper offers a novel study of the effects of environmental risk on cooperation in the VCM game. Our main result is that moving from the standard environment with a deterministic MPCR to the environments in which MPCR is risky does not affect the main patterns of cooperation.

More generally, this study extends the previous literature and furthers our understanding of the effects of environmental randomness on cooperation in the following ways. First, the behavioral reaction to environmental risk seems to be different for competitive and non-competitive risks. In the light of the combined evidence from Fischbacher et al. (2014) (in which the risk involves within-group competition) and our study (in which the calibration of the VCM game is the same, but the risk, whether homogeneous or heterogeneous, always has a non-competitive nature), it seems that the presence of competition might be detrimental for cooperation under environmental risk. This observation echoes the previous work by Krawczyk and Le Lec (2010) who show that competition undermines sharing in the dictator games with risky outcomes. Put together, this body of evidence suggests that social interactions under risk are sensitive to competition which may partially mute other-regarding concerns.

Second, our study contributes to the recent experimental investigations of the effects of environmental randomness on the provision of public goods. Together with the recent studies by Levati and Morone (2013), Boulu-Reshef et al. (2017) and Björk et al. (2016) (but notwithstanding Levati et al., 2009; Cárdenas et al., 2017), the results of our experiment point to the robustness of the standard patterns of cooperation not only across different domains of (non-competitive) risk, but also across different domains of (non-competitive) randomness: risk, ambiguity and uncertainty.

Altogether, we find strong support for the "gold standard" approach to studying human cooperation by means of the Voluntary Contribution Mechanism paradigm in which the marginal per capita return from the public good is deterministic, homogeneous and publicly known. We reckon that standard methodology provides a robust and conservative measure of human cooperation.

Bibliography

Andreoni, J. (1988). Why free ride?: Strategies and learning in public goods experiments. *Journal of Public Economics 37*(3), 291–304.

Björk, L., M. Kocher, P. Martinsson, P. Nam Khanh, et al. (2016). Cooperation under risk and ambiguity.

Bock, O., I. Baetge, and A. Nicklisch (2014). hroot: Hamburg registration and organization online tool. *European Economic Review 71*, 117–120.

Bolton, G. E., J. Brandts, and A. Ockenfels (2005). Fair procedures: Evidence from games involving lotteries. *The Economic Journal 115*(506), 1054–1076.

Bolton, G. E. and A. Ockenfels (2000). ERC: A theory of equity, reciprocity, and competition. *American Economic Review*, 166–193.

Boulu-Reshef, B., S. H. Brott, and A. Zylbersztejn (2017). Does uncertainty deter provision of public goods? *Revue Economique 68*(5), 785–791.

Brock, J. M., A. Lange, and E. Y. Ozbay (2013). Dictating the risk: Experimental evidence on giving in risky environments. *The American Economic Review 103*(1), 415–437.

Cárdenas, J.-C., M. A. Janssen, M. Ale, R. Bastakoti, A. Bernal, J. Chalermphol, Y. Gong, H. Shin, G. Shivakoti, Y. Wang, et al. (2017). Fragility of the provision of local public goods to private and collective risks. *Proceedings of the National Academy of Sciences 114*(5), 921–925.

Cettolin, E., A. Riedl, and G. Tran (2017). Giving in the face of risk. *Journal of Risk and Uncertainty 55*(2-3), 95–118.

Charness, G., U. Gneezy, and A. Imas (2013). Experimental methods: Eliciting risk preferences. *Journal of Economic Behavior & Organization 87*, 43–51.

Charness, G. and M. Rabin (2002). Understanding social preferences with simple tests. *The Quarterly Journal of Economics 117*(3), 817–869.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: a selective survey of the literature. *Experimental Economics 14*(1), 47–83.

Croson, R. T. (1996). Partners and strangers revisited. *Economics Letters 53*(1), 25 – 32.

Dannenberg, A., A. Löschel, G. Paolacci, C. Reif, and A. Tavoni (2015). On the provision of public goods with probabilistic and ambiguous thresholds. *Environmental and Resource Economics 61*(3), 365–383.

Dickinson, D. L. (1998). The voluntary contributions mechanism with uncertain group payoffs. *Journal of Economic Behavior & Organization 35*(4), 517–533.

Falk, A. and U. Fischbacher (2006). A theory of reciprocity. *Games and Economic Behavior 54*(2), 293–315.

Fehr, E. and K. M. Schmidt (1999). A theory of fairness, competition, and cooperation. *The Quarterly Journal of Economics*, 817–868.

Fischbacher, U. (2007). z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics 10*(2), 171–178.

Fischbacher, U. and S. Gächter (2010). Social preferences, beliefs, and the dynamics of free riding in public goods experiments. *The American Economic Review 100*(1), 541–556.

Fischbacher, U., S. Gächter, and E. Fehr (2001). Are people conditionally cooperative? evidence from a public goods experiment. *Economics Letters 71*(3), 397–404.

Fischbacher, U., S. Gächter, and S. Quercia (2012). The behavioral validity of the strategy method in public good experiments. *Journal of Economic Psychology 33*(4), 897–913.

Fischbacher, U., S. Schudy, and S. Teyssier (2014). Heterogeneous reactions to heterogeneity in returns from public goods. *Social Choice and Welfare 43*(1), 195–217.

Fisher, J., R. M. Isaac, J. W. Schatzberg, and J. M. Walker (1995). Heterogenous demand for public goods: Behavior in the voluntary contributions mechanism. *Public Choice 85*(3-4), 249–266.

Fréchette, G. R. (2012, Sep). Session-effects in the laboratory. *Experimental Economics 15*(3), 485–498.

Gangadharan, L. and V. Nemes (2009). Experimental analysis of risk and uncertainty in provisioning private and public goods. *Economic Inquiry 47*(1), 146–164.

Gneezy, U. and J. Potters (1997). An experiment on risk taking and evaluation periods. *The Quarterly Journal of Economics*, 631–645.

Isaac, R. M., K. F. McCue, and C. R. Plott (1985). Public goods provision in an experimental environment. *Journal of Public Economics 26*(1), 51–74.

Isaac, R. M. and J. M. Walker (1988a). Communication and free-riding behavior: The voluntary contribution mechanism. *Economic Inquiry 26*(4), 585–608.

Isaac, R. M. and J. M. Walker (1988b). Group size effects in public goods provision: The voluntary contributions mechanism. *The Quarterly Journal of Economics*, 179–199.

Isaac, R. M., J. M. Walker, and S. H. Thomas (1984). Divergent evidence on free riding: An experimental examination of possible explanations. *Public Choice 43*(2), 113–149.

Jacquemet, N. and A. Zylbersztejn (2014). What drives failure to maximize payoffs in the lab? a test of the inequality aversion hypothesis. *Review of Economic Design 18*(4), 243–264.

Kim, O. and M. Walker (1984). The free rider problem: Experimental evidence. *Public Choice 43*(1), 3–24.

Krawczyk, M. and F. Le Lec (2010). Give me a chance! an experiment in social decision under risk. *Experimental Economics 13*(4), 500–511.

Krawczyk, M. and F. L. Lec (2016). Dictating the risk: Experimental evidence on giving in risky environments: Comment. *The American Economic Review 106*(3), 836–839.

Krawczyk, M. W. (2011, Jan). A model of procedural and distributive fairness. *Theory and Decision 70*(1), 111–128.

Ledyard, J. . (1995). Public goods: A survey of experimental research. *Handbook of Experimental Economics, Princeton University Press, Princeton*, 111–194.

Levati, M. V. and A. Morone (2013). Voluntary contributions with risky and uncertain marginal returns: the importance of the parameter values. *Journal of Public Economic Theory 15*(5), 736–744.

Levati, M. V., A. Morone, and A. Fiore (2009). Voluntary contributions with imperfect information: An experimental study. *Public Choice 138*(1-2), 199–216.

Lévy-Garboua, L., C. Montmarquette, J. Vaksmann, and M. C. Villeval (2017). Voluntary contributions to a mutual insurance pool. *Journal of Public Economic Theory 19*(1), 198–218.

Marcus, D. K., V. Zeigler-Hill, S. H. Mercer, and A. L. Norris (2014). The psychology of spite and the measurement of spitefulness. *Psychological Assessment 26*(2), 563.

Murphy, R. O., K. A. Ackermann, and M. Handgraaf (2011). Measuring social value orientation. *Judgment and Decision Making 6*(8), 771–781.

Neugebauer, T., J. Perote, U. Schmidt, and M. Loos (2009). Selfish-biased conditional cooperation: On the decline of contributions in repeated public goods experiments. *Journal of Economic Psychology 30*(1), 52–60.

Rabin, M. (1993). Incorporating fairness into game theory and economics. *The American Economic Review*, 1281–1302.

Rabin, M. (2002). A perspective on psychology and economics. *European Economic Review 46*(4), 657–685.

Saito, K. (2013). Social preferences under risk: Equality of opportunity versus equality of outcome. *The American Economic Review 103*(7), 3084–3101.

Stoddard, B. (2013). Uncertainty in payoff-equivalent appropriation and provision games. *Working Papers in Economics*.

Stoddard, B. V. et al. (2014). Probabilistic production of a public good. *Economics Bulletin 34*(4), 2427–2442.

Stoop, J., C. Noussair, and D. van Soest (2012). From the lab to the field: Cooperation among fishermen. *Journal of Political Economy 120*(6), 1027–1056.

Trautmann, S. T. (2009). A tractable model of process fairness under risk. *Journal of Economic Psychology 30*(5), 803–813.

Vesely, S. and E. Wengström (2017, March). Risk and Cooperation: Experimental Evidence from Stochastic Public Good Games. *Working Papers in Economics* (2017:3).

Weimann, J. (1994). Individual behaviour in a free riding experiment. *Journal of Public Economics 54*(2), 185–200.

A Appendix

A.1 Simulation procedure

Agent i's utility U_i is defined in (2.3) and depends on π_i as well as the other group members' average payoff $\bar{\pi}_{-i} = \sum_{j \neq i} \frac{\pi_j}{N-1}$.

Agent i's payoff π_i is defined in (2.1) and depends on i's contribution c_i, the other group members' average contribution $\bar{c}_{-i}$, and i's MPCR.

Agent i also considers the remaining group members to be homogeneous with respect to their contribution levels, each contributing $\bar{c}_{-i}$. Thus, agent i uses (2.1) to compute another agent j's payoff π_j that depends on j's contribution $\bar{c}_{-i}$, i's contribution c_i, as well as j's MPCR.

Agent i also anticipates all the possible distributions of MPCR within his group. With K such distributions (denoted $D_1, \ldots, D_K$) along with their respective probabilities (denoted $Pr(D_1), \ldots, Pr(D_K)$), agent i's expected utility from choosing c_i given $\bar{c}_{-i}$ is:

$$EU_i(c_i|\bar{c}_{-i}) = \sum_{k=1}^{K} Pr(D_k) U_i(c_i|\bar{c}_{-i}, D_k) \tag{4}$$

In the baseline treatment, $K = 1$: MPCR=0.4 for all group members with certainty.

In HomR, $K = 2$: either MPCR=0.3 or MPCR=0.5 for all group members, both distributions being equally likely.

In HetR, $K = 8$: there are two possible values of i's MPCR (either high or low, with equal probabilities) and four possible combinations of the MPCR among the remaining group members (either 0, 1, 2, or 3 low MPCR, the rest being high MPCR; their respective probabilities are 0.125, 0.375, 0.375, 0.125).

Finally, for each $\bar{c}_{-i} \in [0, 10]$ (with 0.25 increments) and given his inequality aversion parameter ν_i, agent i chooses $c_i \in [0, 10]$ (with 0.25 increments) that maximizes EU_i from (4).

A.2 Experimental instructions (translated from French)

Instructions: Baseline Treatment

Thank you for participating to this experiment in economics. Please turn off your phone and do not communicate with the others unless we ask you to. If you have any questions, you can press the red button at the left of your desk at any time, we will come to answer you in private.

During this experiment, you are going to make decisions. These decisions can make you earn money. During the whole experiment, we will not talk about Euros, but about Experimental Currency Units (ECU). Your earnings will be computed in ECU, then converted in Euros at the time of the payment. The conversion rate is the following: 10 ECU = 3 Euro. At the end of the session, you will receive your payment. You will be paid in Euros, in cash and in private in a separated room.

This session comprises 2 parts. Your total gain for this session will be the sum of your gains in both parts. The instructions below describe the content of Part 1. The instructions for Part 2 will be distributed at the end of Part 1. During the whole session, your decisions are anonymous.

Preliminary part:

In order to match your answers of the online questionnaire and your answers at this session, please indicate the code we sent you by mail. If you have doubts, please press the red button on the left-hand side of your desk.

Instructions for Part 1:

In this first part, the computer program will randomly form groups of 4 people. At the beginning of the part, each member of the group has 10 ECU. Each group member can invest a part of this amount in a common group project. The amount must be between 0 and 10 ECU. Then, the sum of the amounts invested in the common project is multiplied by 1.6 and equally redistributed between the 4 group members. For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

Your gain is computed in the following way:

$$\text{Your gain} = [10 - (\text{amount invested})] + \frac{1.6 \times \text{sum of amounts invested}}{4} \quad (5)$$

Your task consists in (i) choosing successively 2 "types of amount" that you wish to invest in the common project and (ii) estimating the amount invested by the other group members.

- On the first screen, you need to enter an "unconditional amount". This is the amount you want to invest in the common project independently of the amounts invested by the 3 other group members. Once this amount is chosen, confirm by clicking on the OK button.
- On the second screen, you need to enter "conditional amounts". These are the amounts you want to invest for each average amount invested by your group members. Once these amounts are chosen, confirm by clicking on the OK button.
- On the third screen, you need to estimate what will be the average amount invested in the project by your three group members.

How is your gain computed?

The computer program will randomly select a member of your group:

- If you are not the randomly selected group member, the amount taken into account to compute your gain will be your unconditional amount.
- If you are the randomly selected group member, the amount taken into account to compute your gain will be the conditional amount corresponding to the average of the unconditional amounts of your 3 group members, rounded up to the nearest whole number.

If you estimate exactly the average amount plus or minus 1 ECU, you will receive 5 ECU. Otherwise, you will not receive anything. You will be informed about your earnings for this part at the end of the experiment.

Note that the conditional and unconditional amounts can have an impact on your payment.

The table displayed in these instructions shows your gain in ECU depending on your level of contribution to the project as well as the average level of contribution of your group members.

Before beginning Part 1, you have to reply to a questionnaire that will be distributed.

Please read these instructions again. If you have any questions, please push the red button on the left-hand side of your desk and we will come to answer you in private.

		Average contribution of other group members										
		0	1	2	3	4	5	6	7	8	9	10
Your contribution	0	10	11.2	12.4	13.6	14.8	16	17.2	18.4	19.6	20.8	22
	1	9.4	10.6	11.8	13	14.2	15.4	16.6	17.8	19	20.2	21.4
	2	8.8	10	11.2	12.4	13.6	14.8	16	17.2	18.4	19.6	20.8
	3	8.2	9.4	10.6	11.8	13	14.2	15.4	16.6	17.8	19	20.2
	4	7.6	8.8	10	11.2	12.4	13.6	14.8	16	17.2	18.4	19.6
	5	7	8.2	9.4	10.6	11.8	13	14.2	15.4	16.6	17.8	19
	6	6.4	7.6	8.8	10	11.2	12.4	13.6	14.8	16	17.2	18.4
	7	5.8	7	8.2	9.4	10.6	11.8	13	14.2	15.4	16.6	17.8
	8	5.2	6.4	7.6	8.8	10	11.2	12.4	13.6	14.8	16	17.2
	9	4.6	5.8	7	8.2	9.4	10.6	11.8	13	14.2	15.4	16.6
	10	4	5.2	6.4	7.6	8.8	10	11.2	12.4	13.6	14.8	16

Table 1: Your gain depending on your contribution and on the average contribution of your three group members when the multiplier factor is equal to 1.6

Instructions for Part 2: This part lasts 10 periods.

During this whole part, you belong to the same group as in Part 1. At the beginning of each period, each group member has 10 ECU. Each group member can invest a part of this amount in a common group project. The amount must be between 0 and 10 ECU. Then, the sum of the amounts invested in the common project is multiplied by 1.6 and equally redistributed between the 4 group members. For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

Your gain is computed in the following way:

$$\text{Your gain} = [10 - (\text{amount invested})] + \frac{1.6 \times \text{sum of amounts invested}}{4} \tag{6}$$

At the end of each period, each group member receives information about his/her level of contribution to the project, the total amount invested by the group members, the return of the project, the return of his/her personal account, as well as his/her gain.

How is your gain computed?

For this part, one period will be randomly selected and gains will be added to the gains of Part 1.

Please read these instructions again. If you have any questions, please push the red button on the left-hand side of your desk and we will come to answer you in private.

Questionnaire:

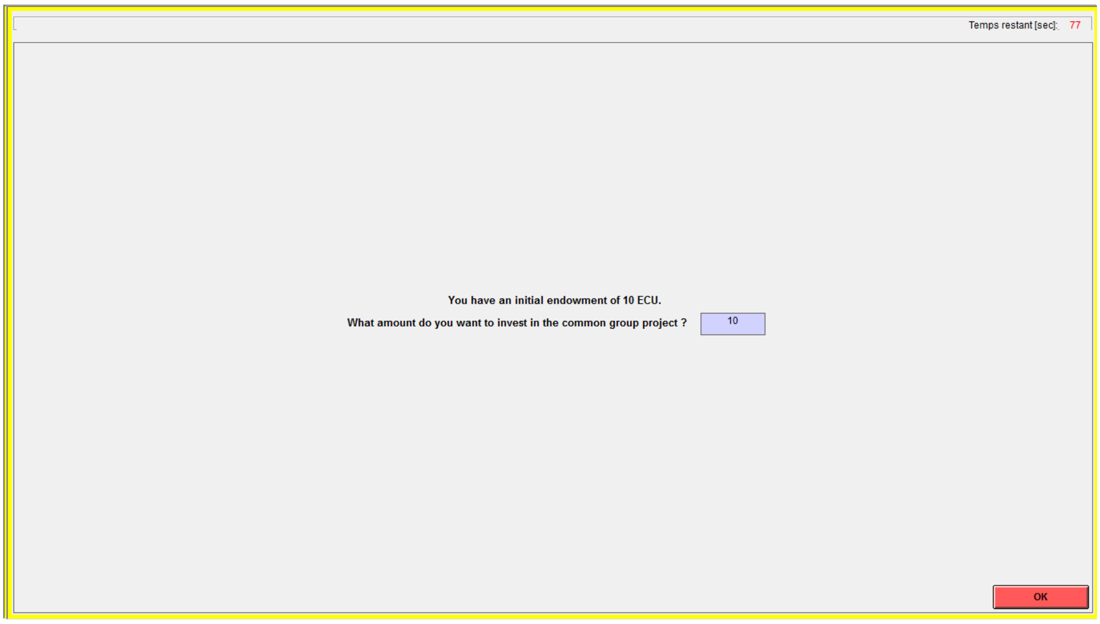
1. How many group members do you have?

    - 1
    - 2
    - 3
    - 4

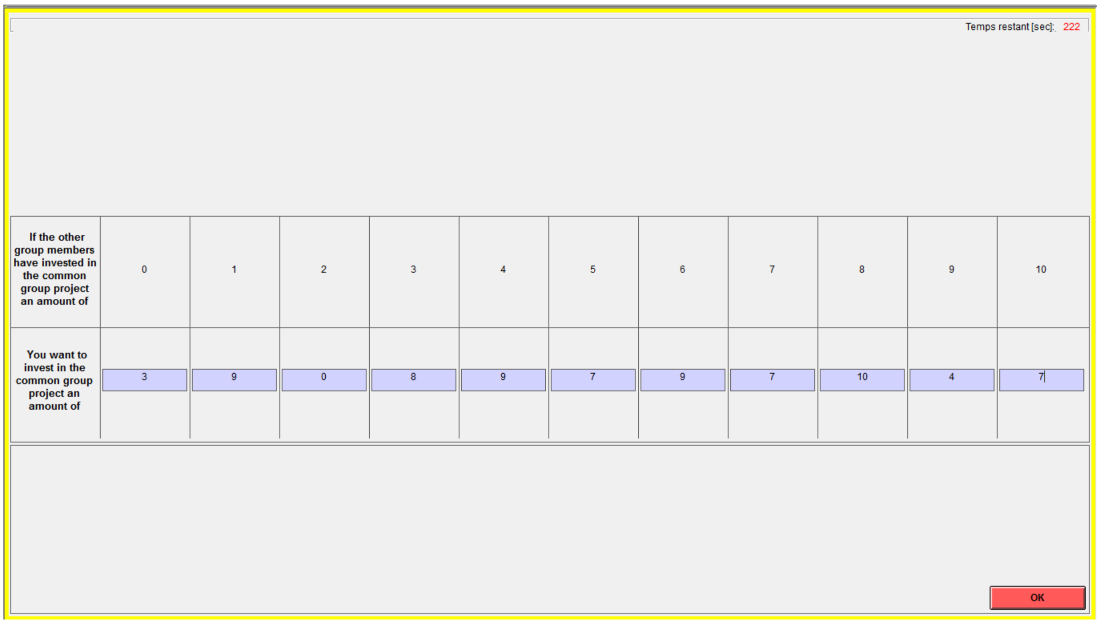
2. After drawing lots, the average contribution of the other group members is equal to 5 ECU. Compute your profit if your finale contribution is:

    - 0 ECU
    - 5 ECU
    - 10 ECU

In the following questions, we consider some randomly obtained amounts of a fictional participant.



Screen 1: Unconditional amount



Screen 2: Conditional amounts

Screen 3: Estimation of the contributions

3. Suppose that the participant is randomly selected and that the average contribution of the other members is equal to 6.6 ECU. Which amount will be selected for his/her contribution?

   - 9
   - 7
   - 5
   - 10

4. Suppose that the participant is not randomly selected and that the average contribution of the other group members is equal to 6.6 ECU. Which amount will be selected for his/her contribution?

   - 9
   - 7
   - 5
   - 10

5. The average contribution of the other group members is equal to 6.6 ECU. Did the participant earn the 5 ECU that depend on his/her estimation concerning the average level of contribution of his/her group members?

   - Yes
   - No

Instructions: Homogeneous Risk Treatment

Thank you for participating to this experiment in economics. Please turn off your phone and do not communicate with the others unless we ask you to. If you have any questions, you can press the red button at the left of your desk at any time, we will come to answer you in private.

During this experiment, you are going to make decisions. These decisions can make you earn money. During the whole experiment, we will not talk about Euros, but about Experimental Currency Units (ECU). Your earnings will be computed in ECU, then converted in Euros at the time of the payment. The conversion rate is the following: 10 ECU = 3 Euro.

At the end of the session, you will receive your payment. You will be paid in Euros, in cash and in private in a separated room.

This session comprises 2 parts. Your total gain for this session will be the sum of your gains in both parts.

The instructions below describe the content of Part 1. The instructions for Part 2 will be distributed at the end of Part 1. During the whole session, your decisions are anonymous.

Preliminary part:

In order to match your answers of the online questionnaire and your answers at this session, please indicate the code we sent you by mail. If you have doubts, please press the red button on the left-hand side of your desk.

Instructions for Part 1:

In this first part, the computer program will randomly form groups of 4 people. At the beginning of the part, each member of the group has 10 ECU. Each group member can invest a part of this amount in a common group project. The amount must be between 0 and 10 ECU. Then, the sum of the amounts invested in the common project is multiplied either by 1.2 or by 2 (each possibility has a 50% chance to be realized) and equally redistributed between the 4 group members.

For all the group members, the amount that is not invested in the common project is

stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.
Your gain is computed in the following way:

$$\text{Your gain} = [10 - (\text{amount invested})] + \frac{r \times \text{sum of amounts invested}}{4} \tag{7}$$

where r is the multiplier factor of the common project and is worth either 1.2 or 2 depending on the outcome of the random draw.
Your task consists in (i) choosing successively 2 "types of amount" that you wish to invest in the common project and (ii) estimating the amount invested by the other group members.

- On the first screen, you need to enter an "unconditional amount". This is the amount you want to invest in the common project independently of the amounts invested by the 3 other group members. Once this amount is chosen, confirm by clicking on the OK button.
- On the second screen, you need to enter "conditional amounts". These are the amounts you want to invest for each average amount invested by your group members. Once these amounts are chosen, confirm by clicking on the OK button.
- On the third screen, you need to estimate what will be the average amount invested in the project by your three group members.

How is your gain computed?
The computer program will randomly select a member of your group:

- If you are not the randomly selected group member, the amount taken into account to compute your gain will be your unconditional amount.
- If you are the randomly selected group member, the amount taken into account to compute your gain will be the conditional amount corresponding to the average of

the unconditional amounts of your 3 group members, rounded up to the nearest whole number.

If you estimate exactly the average amount plus or minus 1 ECU, you will receive 5 ECU. Otherwise, you will not receive anything. You will be informed about your earnings for this part at the end of the experiment.

Note that the conditional and unconditional amounts can have an impact on your payment.

The table displayed in these instructions shows your gain in ECU depending on your level of contribution to the project as well as the average level of contribution of your group members.

Before beginning Part 1, you have to reply to a questionnaire that will be distributed.

Please read these instructions again. If you have any questions, please push the red button on the left-hand side of your desk and we will come to answer you in private.

		Average contribution of other group members										
		0	1	2	3	4	5	6	7	8	9	10
	0	10	10.9	11.8	12.7	13.6	14.5	15.4	16.3	17.2	18.1	19
	1	9.3	10.2	11.1	12	12.9	13.8	14.7	15.6	16.5	17.4	18.3
	2	8.6	9.5	10.4	11.3	12.2	13.1	14	14.9	15.8	16.7	17.6
	3	7.9	8.8	9.7	10.6	11.5	12.4	13.3	14.2	15.1	16	16.9
	4	7.2	8.1	9	9.9	10.8	11.7	12.6	13.5	14.4	15.3	16.2
Your contribution	5	6.5	7.4	8.3	9.2	10.1	11	11.9	12.8	13.7	14.6	15.5
	6	5.8	6.7	7.6	8.5	9.4	10.3	11.2	12.1	13	13.9	14.8
	7	5.1	6	6.9	7.8	8.7	9.6	10.5	11.4	12.3	13.2	14.1
	8	4.4	5.3	6.2	7.1	8	8.9	9.8	10.7	11.6	12.5	13.4
	9	3.7	4.6	5.5	6.4	7.3	8.2	9.1	10	10.9	11.8	12.7
	10	3	3.9	4.8	5.7	6.6	7.5	8.4	9.3	10.2	11.1	12

Table 1: Your gain depending on your contribution and on the average contribution of your three group members when the multiplier factor is equal to 1.2

		Average contribution of other group members										
		0	1	2	3	4	5	6	7	8	9	10
	0	10	11.5	13	14.5	16	17.5	19	20.5	22	23.5	25
	1	9.5	11	12.5	14	15.5	17	18.5	20	21.5	23	24.5
	2	9	10.5	12	13.5	15	16.5	18	19.5	21	22.5	24
	3	8.5	10	11.5	13	14.5	16	17.5	19	20.5	22	23.5
	4	8	9.5	11	12.5	14	15.5	17	18.5	20	21.5	23
Your contribution	5	7.5	9	10.5	12	13.5	15	16.5	18	19.5	21	22.5
	6	7	8.5	10	11.5	13	14.5	16	17.5	19	20.5	22
	7	6.5	8	9.5	11	12.5	14	15.5	17	18.5	20	21.5
	8	6	7.5	9	10.5	12	13.5	15	16.5	18	19.5	21
	9	5.5	7	8.5	10	11.5	13	14.5	16	17.5	19	20.5
	10	5	6.5	8	9.5	11	12.5	14	15.5	17	18.5	20

Table 2: Your gain depending on your contribution and on the average contribution of your three group members when the multiplier factor is equal to 2

Instructions for Part 2: This part lasts 10 periods.

During this whole part, you belong to the same group as in Part 1. At the beginning of each period, each group member has 10 ECU. Each group member can invest a part of this amount in a common group project. The amount must be between 0 and 10 ECU. Then, the sum of the amounts invested in the common project is multiplied either by 1.2 or by 2 (each possibility has a 50% chance to be realized) and equally redistributed between the 4 group members.

For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

Your gain is computed in the following way:

$$\text{Your gain} = [10 - (\text{amount invested})] + \frac{r \times \text{sum of amounts invested}}{4} \tag{8}$$

where r is the multiplier factor of the common project and is worth either 1.2 or 2 depending on the outcome of the random draw.

Your task consists in choosing the amount you want to invest in the common project.

At the end of each period, each group member receives information about his/her level of contribution to the project, the total amount invested by the group members, the return of the project, the return of his/her personal account, as well as his/her gain.

How is your gain computed?

For this part, one period will be randomly selected and gains will be added to the gains of Part 1.

Please read these instructions again. If you have any questions, please push the red button on the left-hand side of your desk and we will come to answer you in private.

Questionnaire:

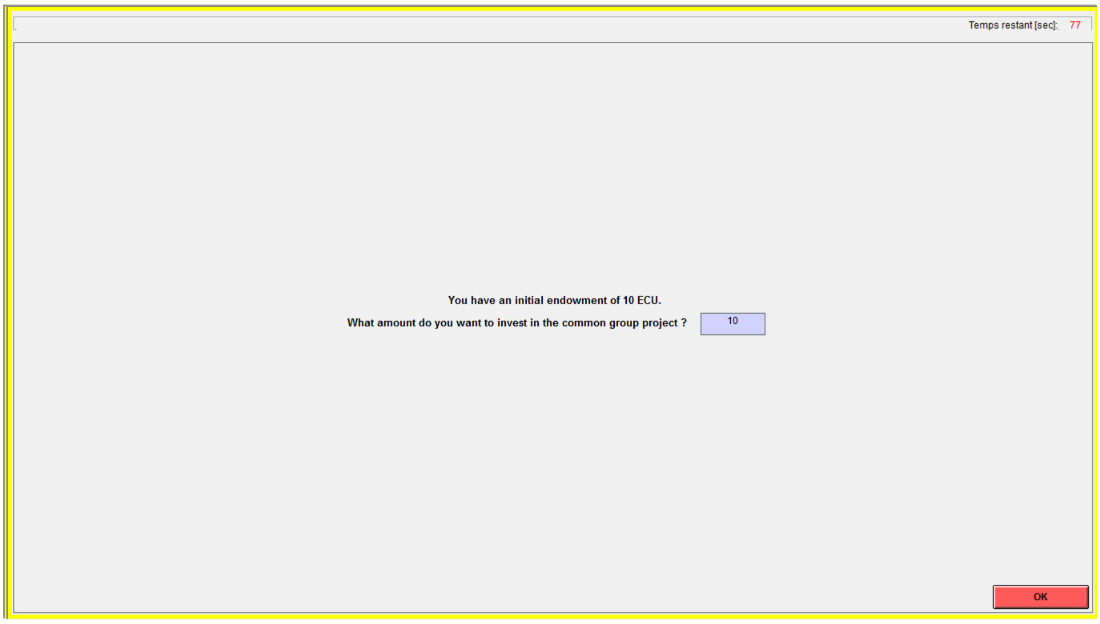
1. How many group members do you have?

    - 1
    - 2
    - 3
    - 4

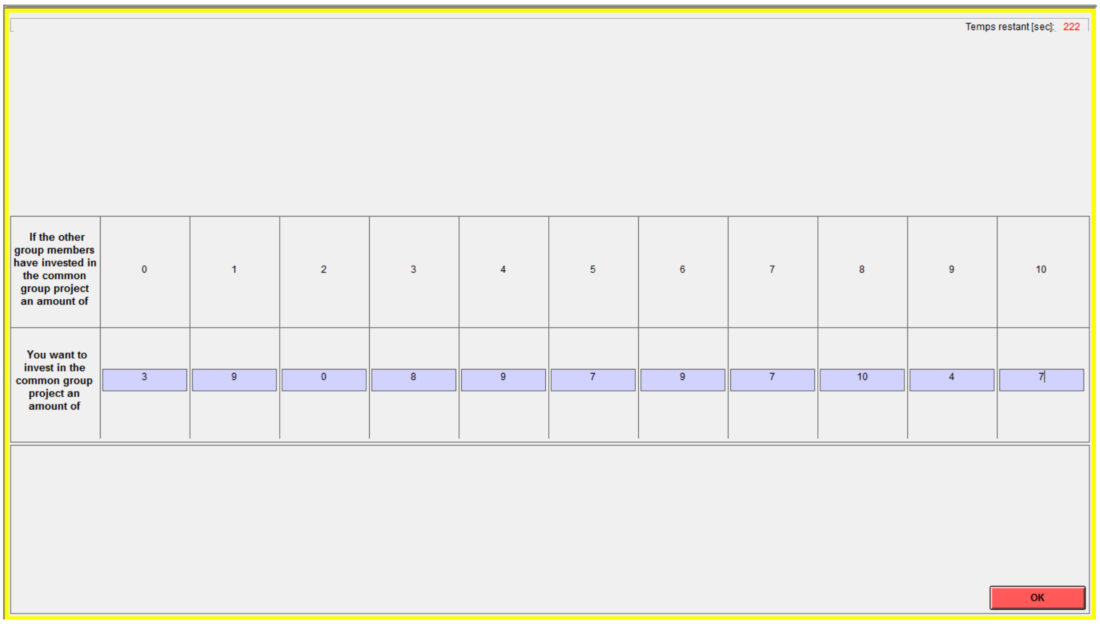
2. The average contribution of your three group members is equal to 5 ECU. Compute your profit if your finale contribution is 7:

    - If the sum of amounts invested in the common project has been multiplied by 1.2
    - If the sum of amounts invested in the common project has been multiplied by 2

In the following questions, we consider some randomly obtained amounts of a fictional participant.



Screen 1: Unconditional amount



Screen 2: Conditional amounts

Screen 3: Estimation of the contributions

3. Suppose that the participant is randomly selected and that the average contribution of the other members is equal to 6.6 ECU. Which amount will be selected for his/her contribution?

    - 9
    - 7
    - 5
    - 10

4. Suppose that the participant is not randomly selected and that the average contribution of the other group members is equal to 6.6 ECU. Which amount will be selected for his/her contribution?

    - 9
    - 7
    - 5
    - 10

5. The average contribution of the other group members is equal to 6.6 ECU. Did the participant earn the 5 ECU that depend on his/her estimation concerning the average level of contribution of his/her group members?

    - Yes
    - No

Instructions: Heterogeneous Risk Treatment

Thank you for participating to this experiment in economics. Please turn off your phone and do not communicate with the others unless we ask you to. If you have any questions, you can press the red button at the left of your desk at any time, we will come to answer you in private.

During this experiment, you are going to make decisions. These decisions can make you earn money. During the whole experiment, we will not talk about Euros, but about Experimental Currency Units (ECU). Your earnings will be computed in ECU, then converted in Euros at the time of the payment. The conversion rate is the following: 10 ECU = 3 Euro.

At the end of the session, you will receive your payment. You will be paid in Euros, in cash and in private in a separated room.

This session comprises 2 parts. Your total gain for this session will be the sum of your gains in both parts.

The instructions below describe the content of Part 1. The instructions for Part 2 will be distributed at the end of Part 1. During the whole session, your decisions are anonymous.

Preliminary part:

In order to match your answers of the online questionnaire and your answers at this session, please indicate the code we sent you by mail. If you have doubts, please press the red button on the left-hand side of your desk.

Instructions for Part 1:

In this first part, the computer program will randomly form groups of 4 people. At the beginning of the part, each member of the group has 10 ECU. Each group member can invest a part of this amount in a common group project. The amount must be between 0 and 10 ECU. Once every group member has chosen the amount he/she wants to invest in the common project, a random draw determines the return of the project for each group member. Each group member has a 50% chance to receive either the equivalent of 30% of the total amount invested in the common project, or the equivalent of 50% of the

total amount invested in the common project. This random draw is individual for each group member. Thus, the outcomes of the random draw may differ across the members of a group.
For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.
Your gain is computed in the following way:

$$\text{Your gain} = [10 - (\text{amount invested})] + p \times \text{sum of amounts invested} \tag{9}$$

where p is worth either 30% or 50% depending on the outcome of the random draw.
Your task consists in (i) choosing successively 2 "types of amount" that you wish to invest in the common project and (ii) estimating the amount invested by the other group members.

- On the first screen, you need to enter an "unconditional amount". This is the amount you want to invest in the common project independently of the amounts invested by the 3 other group members. Once this amount is chosen, confirm by clicking on the OK button.

- On the second screen, you need to enter "conditional amounts". These are the amounts you want to invest for each average amount invested by your group members. Once these amounts are chosen, confirm by clicking on the OK button.

- On the third screen, you need to estimate what will be the average amount invested in the project by your three group members.

How is your gain computed?
The computer program will randomly select a member of your group:

- If you are not the randomly selected group member, the amount taken into account to compute your gain will be your unconditional amount.
- If you are the randomly selected group member, the amount taken into account to compute your gain will be the conditional amount corresponding to the average of the unconditional amounts of your 3 group members, rounded up to the nearest whole number.

If you estimate exactly the average amount plus or minus 1 ECU, you will receive 5 ECU. Otherwise, you will not receive anything. You will be informed about your earnings for this part at the end of the experiment.

Note that the conditional and unconditional amounts can have an impact on your payment.

The table displayed in these instructions shows your gain in ECU depending on your level of contribution to the project as well as the average level of contribution of your group members.

Before beginning Part 1, you have to reply to a questionnaire that will be distributed.

Please read these instructions again. If you have any questions, please push the red button on the left-hand side of your desk and we will come to answer you in private.

		Average contribution of other group members										
		0	1	2	3	4	5	6	7	8	9	10
Your contribution	0	10	10.9	11.8	12.7	13.6	14.5	15.4	16.3	17.2	18.1	19
	1	9.3	10.2	11.1	12	12.9	13.8	14.7	15.6	16.5	17.4	18.3
	2	8.6	9.5	10.4	11.3	12.2	13.1	14	14.9	15.8	16.7	17.6
	3	7.9	8.8	9.7	10.6	11.5	12.4	13.3	14.2	15.1	16	16.9
	4	7.2	8.1	9	9.9	10.8	11.7	12.6	13.5	14.4	15.3	16.2
	5	6.5	7.4	8.3	9.2	10.1	11	11.9	12.8	13.7	14.6	15.5
	6	5.8	6.7	7.6	8.5	9.4	10.3	11.2	12.1	13	13.9	14.8
	7	5.1	6	6.9	7.8	8.7	9.6	10.5	11.4	12.3	13.2	14.1
	8	4.4	5.3	6.2	7.1	8	8.9	9.8	10.7	11.6	12.5	13.4
	9	3.7	4.6	5.5	6.4	7.3	8.2	9.1	10	10.9	11.8	12.7
	10	3	3.9	4.8	5.7	6.6	7.5	8.4	9.3	10.2	11.1	12

Table 1: Your gains depending on your contribution and on the average contribution of your three group members if what you receive equals 30% of the value of the group project

		Average contribution of other group members										
		0	1	2	3	4	5	6	7	8	9	10
Your contribution	0	10	11.5	13	14.5	16	17.5	19	20.5	22	23.5	25
	1	9.5	11	12.5	14	15.5	17	18.5	20	21.5	23	24.5
	2	9	10.5	12	13.5	15	16.5	18	19.5	21	22.5	24
	3	8.5	10	11.5	13	14.5	16	17.5	19	20.5	22	23.5
	4	8	9.5	11	12.5	14	15.5	17	18.5	20	21.5	23
	5	7.5	9	10.5	12	13.5	15	16.5	18	19.5	21	22.5
	6	7	8.5	10	11.5	13	14.5	16	17.5	19	20.5	22
	7	6.5	8	9.5	11	12.5	14	15.5	17	18.5	20	21.5
	8	6	7.5	9	10.5	12	13.5	15	16.5	18	19.5	21
	9	5.5	7	8.5	10	11.5	13	14.5	16	17.5	19	20.5
	10	5	6.5	8	9.5	11	12.5	14	15.5	17	18.5	20

Table 2: Your Your gains depending on your contribution and on the average contribution of your three group members if what you receive equals 50% of the value of the group project

Instructions for Part 2: This part lasts 10 periods.

During this whole part, you belong to the same group as in Part 1. At the beginning of each period, each group member has 10 ECU. Each group member can invest a part of this amount in a common group project. The amount must be between 0 and 10 ECU. Once every group member has chosen the amount he/she wants to invest in the common project, a random draw determines the return of the project for each group member. Each group member has a 50% chance to receive either the equivalent of 30% of the total amount invested in the common project, or the equivalent of 50% of the total amount invested in the common project. This random draw is individual for each group member. Thus, the outcomes of the random draw may differ across the members of a group.

For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

Your gain is computed in the following way:

$$\text{Your gain} = [10 - (\text{amount invested})] + p \times \text{sum of amounts invested} \qquad (10)$$

where p is worth either 30% or 50% depending on the outcome of the random draw.

Your task consists in choosing the amount you want to invest in the common project.

At the end of each period, each group member receives information about his/her level of contribution to the project, the total amount invested by the group members, the return of the project, the return of his/her personal account, as well as his/her gain.

How is your gain computed?

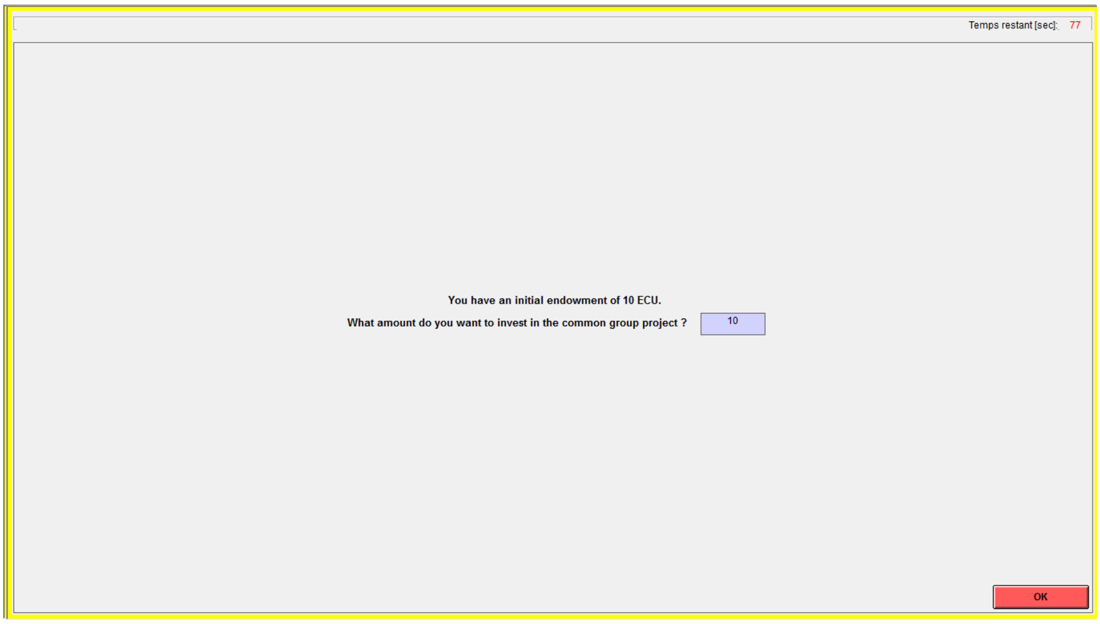
For this part, one period will be randomly selected and gains will be added to the gains of Part 1.

Please read these instructions again. If you have any questions, please push the red button on the left-hand side of your desk and we will come to answer you in private.

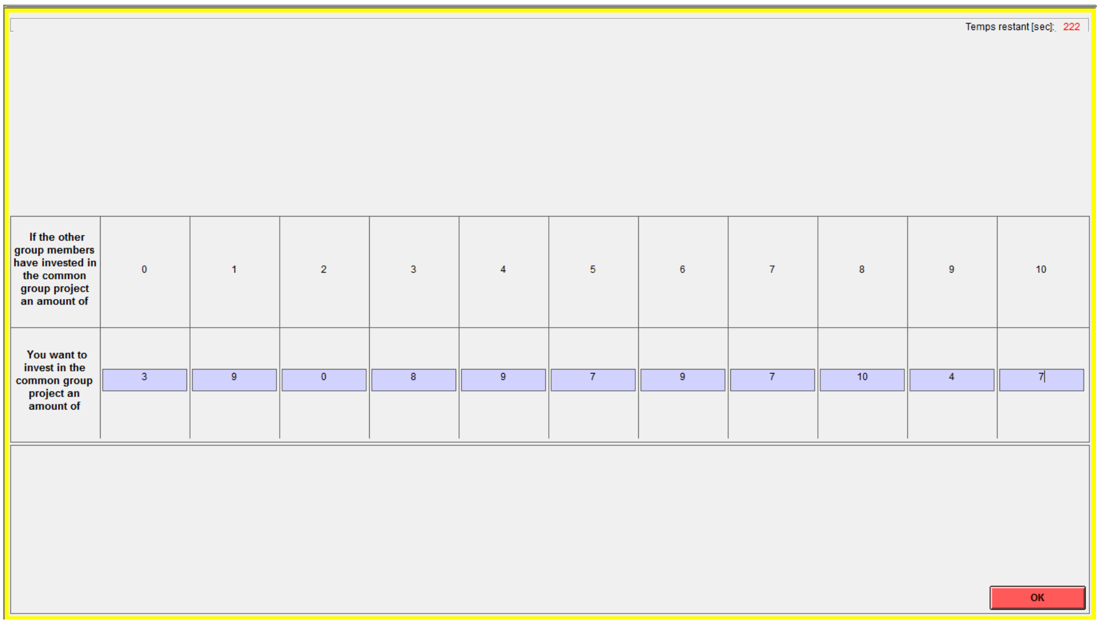
Questionnaire:

1. How many group members do you have?
    - 1
    - 2
    - 3
    - 4
2. After the random draw, every group member will for sure receive the same proportion, p, of the project?
    - Yes
    - No
3. The average contribution of the other group members is equal to 5 ECU. Compute your profit if your finale contribution is 7:
    - If the proportion of the common project that you receive is 30%
    - If the proportion of the common project that you receive is 50%

In the following questions, we consider some randomly obtained amounts of a fictional participant.



Screen 1: Unconditional amount



Screen 2: Conditional amounts

Screen 3: Estimation of the contributions

4. Suppose that the participant is randomly selected and that the average contribution of the other members is equal to 6.6 ECU. Which amount will be selected for his/her contribution?

    - 9
    - 7
    - 5
    - 10

5. Suppose that the participant is not randomly selected and that the average contribution of the other group members is equal to 6.6 ECU. Which amount will be selected for his/her contribution?

    - 9
    - 7
    - 5
    - 10

6. The average contribution of the other group members is equal to 6.6 ECU. Did the participant earn the 5 ECU that depend on his/her estimation concerning the average level of contribution of his/her group members?

    - Yes
    - No

A.3 Spitfulness Scale based on Marcus et al. (2014)

1. It might be worth risking my reputation in order to spread gossip about somone I did not like.

2. If I am going to my car in a crowded parking lot and it appears that another driver wants my parking space, then I will make sure to take my time pulling out of the parking space.

3. I hope that elected officials are successful in their efforts to improve my community even if I opposed their election. (reverse scored)

4. If my neighbor complained that I was playing my music too loud, then I might turn up the music even louder just to irritate him or her, even if meant I could get fined.

5. If I had the opportunity, then I would gladly pay a small sum of money to see a classmate who I do not like fail his or her final exam.

6. There have been times when I was willing to suffer some small harm so that I could punish someone else who deserved it.

7. I would rather no one get extra credit in a class if it meant that others would receive more credit than me.

8. If I opposed the election of an official, then I would be glad to see him or her fail even if their failure hurt my community.

9. I would be willing to take a punch if it meant that someone I did not like would receive two punches.

10. I would be willing to pay more for some goods and services if other people I did not like had to pay even more.

11. If I was one of the last students in a classroom taking an exam and I noticed that the instructor looked impatient, I would be sure to take my time finishing the exam just to irritate him or her.

12. If my neighbor complained about the appearance of my front yard, I would be tempted to make it look worse just to annoy him or her.

13. I would take on extra work at my job if it meant that one of my co-workers who I did not like would also have to do extra work.

14. I would be happy receiving extra credit in a class even if other students received more points than me. (reverse scored)

15. Part of me enjoys seeing the people I do not like fail even if their failure hurts me in some way.

16. If I am checking out at a store and I feel like the person in line behind me is rushing me, then I will sometimes slow down and take exra time to pay.

17. It is sometimes worth a little suffering on my part to see others receive the punishment they deserve.

A.4 Non-parametric analysis

A.5 Non-parametric results on the randomization of risk preferences and other-regarding preferences across treatments

Figure A.1 – Gneezy Potters risk preferences distributions by treatment

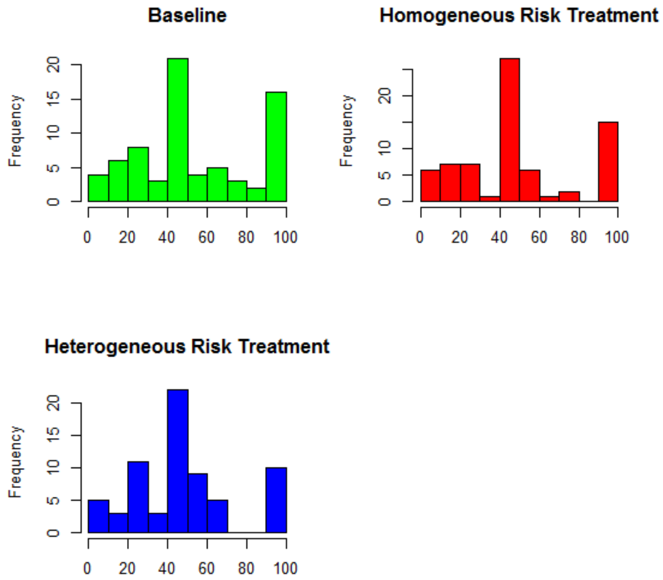


Figure A.1 presents the distributions of investment choices in the Gneezy-Potters test across the three treatments. Kruskal-Wallis test does not reject the null hypothesis that these outcomes come from the same distribution ($p = 0.661$).

A.6 Non-parametric support for Result 1: conditional cooperation

Kruskal-Wallis test is used to check if conditional contributions across treatments come from the same distribution. We replicate the results of the parametric F-test with one slight difference: p associated with the average contribution conditional on other members' average contribution of 1 becomes weakly significant. Altogether, we reject the null hypothesis that the conditional contributions come from the same distribution for three values of the other players' average contribution: the value of 1 ($p = 0.055$), the value of 2 ($p = 0.030$) and the value of 4 ($p = 0.028$); neither result remains significant once we apply the Bonferroni correction for multiple comparisons. These results hold after excluding pure free-riders from the analyzed sample (with $p = 0.062$, $p = 0.024$, and $p = 0.019$, respectively).

A.7 Non-parametric support for Result 2: unconditional contributions and beliefs

Figure A.2 – Distributions of unconditional contributions by treatment

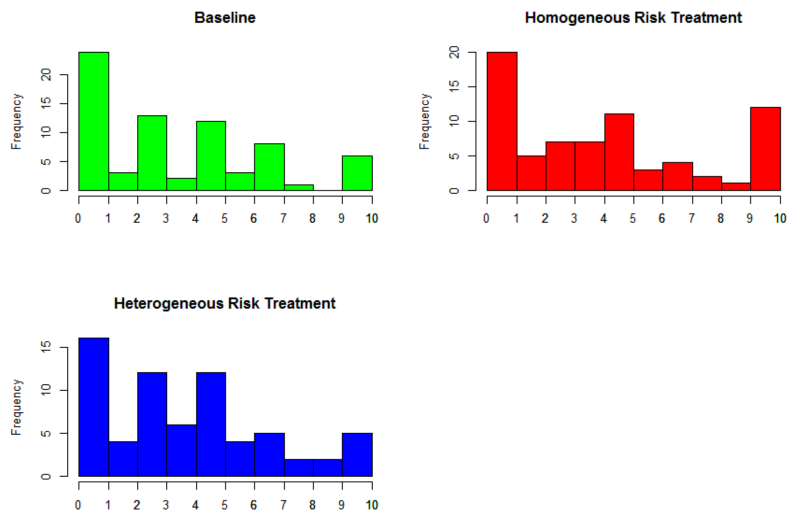
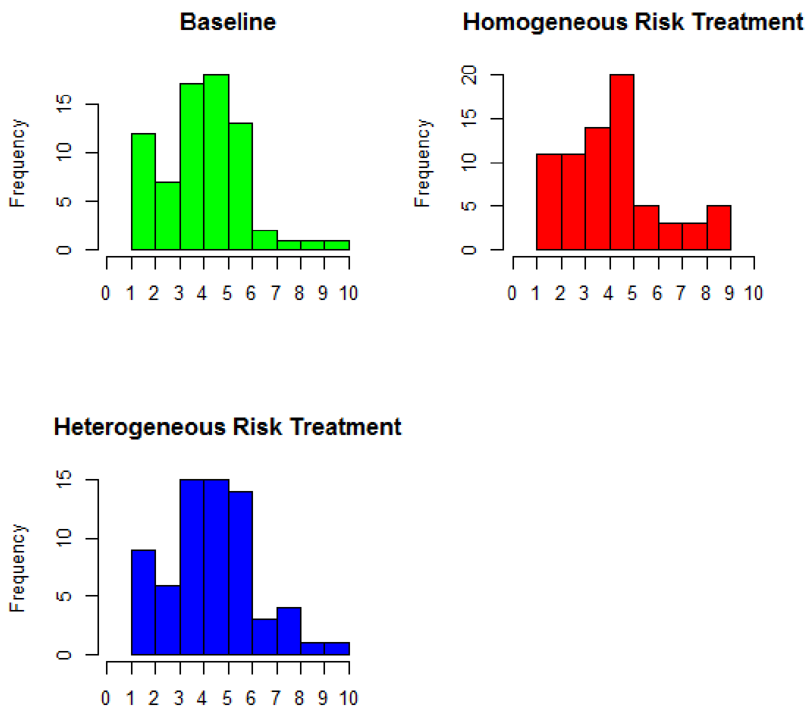


Figure A.2 shows the distributions of unconditional contributions across the three treatments. Kruskal-Wallis test does not reject the null hypothesis that these outcomes come from the same distribution ($p = 0.519$).

Figure A.3 presents the distributions of beliefs about the group members' average contribution to the public good. Kruskal-Wallis test does not reject the null hypothesis that these outcomes come from the same distribution ($p = 0.484$).

Figure A.3 – Distributions of beliefs by treatment



Spearman's correlation coefficients for these two variables are all significant at the 1% level and given as follows. Baseline treatment: 0.531; HetR treatment: 0.578; HomR treatment: 0.677.

A.8 Non-parametric support for Result 4: round 1 and round 10 contributions

For the repeated VCM game, Kruskal-Wallis test does not reject the null hypothesis that the contributions in the repeated VCM game are drawn from the same distribution in round 1 ($p = 0.312$, individual contribution used as an independent observation unit) and in round 10 ($p = 0.665$, group average contribution used as an independent observation unit).

A.9 Non-parametric support for Result 5: average group contributions

Kruskal-Wallis test rejects the null hypothesis that the average group contributions in the repeated VCM game come from the same distribution ($p = 0.015$). Pairwise comparisons based on ranksum tests yield the following results. Comparing the baseline treatment and the HetR treatment, we do not reject the null hypothesis that the average group contributions come from the same distributions ($p = 0.137$). However, the distribution of the average group contributions in the HomR treatment is (weakly) significantly different than in either of the remaining treatments (baseline: $p = 0.008$, HetR: $p = 0.077$).

A.10 Additional tobit regressions

Table A.1 – Unconditional contributions, beliefs and individual characteristics: tobit regressions

Dep. variable:	Beliefs			Uncond. contribution					
Model:	M1	M2	M3	M4	M5	M6	M7	M8	M9
Treatment:	Base	HetR	HomR	Base	HetR	HomR	Base	HetR	HomR
Intercept	4.404^a	3.715^a	4.305^a	0.929	2.277^b	1.740	-3.968	-1.717	-5.517^a
	(0.516)	(0.529)	(0.554)	(1.353)	(1.024)	(1.569)	(1.759)	(1.204)	(1.654)
Beliefs	—	—		—	—	—	1.158^a	1.056^a	1.718^a
							(0.287)	(0.213)	(0.257)
$1[Prosocial]$	-0.028	0.304	-0.025	1.527	0.632	2.770^c	1.429	0.378	2.574^b
	(0.432)	(0.469)	(0.526)	(1.104)	(0.910)	(1.441)	(0.973)	(0.766)	(1.001)
GP score	0.000	0.018^b	0.004	0.025	0.026	0.023	0.022	0.008	0.016
	(0.007)	(0.009)	(0.008)	(0.019)	(0.017)	(0.024)	(0.017)	(0.014)	(0.017)
N (total/left-/right-censored)	72/0/1	68/0/1	72/0/0	72/20/6	68/11/5	72/18/12	72/20/6	68/11/5	72/18/12
$Prob > \chi^2$	0.997	0.103	0.912	0.192	0.231	0.113	0.000	0.000	0.000

Note. Estimates from double-censored tobit regressions. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. Dependent variables are: player's beliefs about other group members' average contribution to the public good (M1-M3), and player's unconditional contribution to the public good (M4-M9). In all the models, the set of explanatory variables includes individual characteristics: $1[Prosocial]$ (dummy variable set to 1 if an individual's type in the SVO task is prosocial, and 0 otherwise), and the Gneezy-Potters test score (GP score). In addition, models M7-M9 also include individual's beliefs about other group members' average contribution to the public good as an independent variable.

Table A.2 – The patterns of cooperation over time and across treatments: tobit regressions

	Tobit			
	Dep. variable: contribution in round t			
Model:	M1	M2	M3	M4
Observations:	$t = 1$	$t = 10$	$t \in [1; 10]$	$t \in [1; 10]$
Intercept (β_0)	3.056[a]	-4.856[a]	-0.271	2.963[a]
	(0.568)	(1.391)	(0.612)	(0.535)
$1[HomR]$ (β_1)	1.171	1.226	2.734[a]	1.226
	(0.799)	(1.856)	(0.953)	(0.835)
$1[HetR]$ (β_2)	0.397	0.225	0.995	0.428
	(0.806)	(2.012)	(0.808)	(0.656)
$1[round2-3]$ (β_3)				-1.353[b]
				(0.633)
$1[round4-5]$ (β_4)				-2.583[a]
				(0.687)
$1[round6-7]$(β_5)				-4.145[a]
				(0.892)
$1[round8-9]$ (β_6)				-5.232[a]
				(0.985)
$1[round10]$ (β_7)				-6.010[a]
				(1.080)
$1[round2-3] \times 1[HomR]$ (β_8)				1.864[b]
				(0.792)
$1[round4-5] \times 1[HomR]$ (β_9)				1.672
				(1.071)
$1[round6-7] \times 1[HomR]$ (β_{10})				2.337[c]
				(1.279)
$1[round8-9] \times 1[HomR]$ (β_{11})				1.726
				(1.391)
$1[round10] \times 1[HomR]$ (β_{12})				-0.241
				(1.626)
$1[round2-3] \times 1[HetR]$ (β_{13})				0.264
				(0.769)
$1[round4-5] \times 1[HetR]$ (β_{14})				0.646
				(0.880)
$1[round6-7] \times 1[HetR]$ (β_{15})				1.056
				(1.151)
$1[round8-9] \times 1[HetR]$ (β_{16})				0.986
				(1.205)
$1[round10] \times 1[HetR]$ (β_{17})				-0.270
				(1.530)
N (total/left-/right-censored)	212/49/24	212/154/6	2120/930/138	2120/930/138
$Prob > \chi^2$	0.330	0.793	0.022	0.000

Note. Estimates from double-censored tobit regressions. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. In all models, the set of explanatory variables includes treatment dummies. In M4, it also includes (pairwise) round dummies and their interactions with treatment dummies. In M2-M4, residuals are clustered at the group level (53 clusters), standard errors are computed using the leave-one-out jackknife procedure.

Table A.3 – Present contributions and random MPCR in the past: tobit regressions

	Dep. variable: contribution in round t			
Model:	M1	M2	M3	M4
Treatment:	HetR	HetR	HomR	HomR
Intercept	1.241^{c}	0.221	3.724^{b}	3.220
	(0.681)	(1.214)	(1.634)	(2.508)
$1[\bar{\alpha}_{t-1}]$	0.453	0.174	-0.660	-1.006
	(0.379)	(0.888)	(0.954)	(1.487)
$Freq(\bar{\alpha})_{(1;t-2)}$	—	0.064	—	0.612
		(1.376)		(2.530)
$1[\bar{\alpha}_{t-1}] \times Freq(\bar{\alpha})_{(1;t-2)}$	—	0.912	—	0.195
		(1.498)		(2.956)
Round (dummy variables):				
3	-0.800	—	-0.319	—
	(0.588)		(0.574)	
4	-0.922	-0.091	-1.175	-0.786
	(0.599)	(0.496)	(0.763)	(0.726)
5	-1.396^{c}	-0.599	-2.292^{b}	-1.957^{c}
	(0.669)	(0.529)	(0.937)	(0.973)
6	-1.965^{b}	-1.159	-2.321^{b}	-1.984^{c}
	(0.800)	(0.753)	(0.828)	(1.020)
7	-2.439^{b}	-1.669^{c}	-3.317^{a}	-2.984^{b}
	(0.920)	(0.885)	(0.948)	(1.194)
8	-3.395^{a}	-2.635^{a}	-3.882^{a}	-3.518^{a}
	(1.035)	(0.869)	(0.931)	(1.189)
9	-3.247^{a}	-2.460^{a}	-5.349^{a}	-4.973^{a}
	(0.844)	(0.521)	(1.326)	(1.673)
10	-5.179^{a}	-4.466^{a}	-7.622^{a}	-7.294^{a}
	(1.072)	(0.747)	(1.499)	(1.844)
$1[Prosocial]$	3.082^{a}	3.100^{a}	1.574	1.636
	(0.570)	(0.668)	(1.427)	(1.479)
GP score	0.002	0.002	0.018	0.016
	(0.010)	(0.011)	(0.015)	(0.015)
N (total/left-/right-censored)	612/280/23	544/264/20	648/248/75	576/236/61
$Prob > \chi^2$	0.000	0.000	0.002	0.012

Note. Estimates from double-censored tobit regressions. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. Observations come from rounds 2-10 in M1 and M3, and from rounds 3-10 in M2 and M4. Residuals are clustered at the group level (17 clusters in HetR, 18 clusters in HomR), standard errors are computed using the leave-one-out jackknife procedure.

A.11 Econometric support for footnote 28

Table A.4 – Econometric analysis of behavior in the repeated baseline VCM game

	Dep. variable: contribution in round t	
Model:	OLS	Double-censored tobit
Intercept	3.334^a	2.975^b
	(0.647)	(1.247)
Round (dummy variables):		
2	-0.792^b	-1.047^c
	(0.351)	(0.567)
3	-.931^b	-1.644^b
	(0.407)	(0.751)
4	-1.472^a	-2.480^b
	(0.479)	(0.932)
5	-1.389^a	-2.573^a
	(0.310)	(0.624)
6	-1.986^a	-3.801^a
	(0.315)	(0.803)
7	-2.111^a	-4.290^a
	(0.445)	(1.102)
8	-2.222^a	-4.559^a
	(0 .405)	(0.993)
9	-2.597^a	-5.693^a
	(0.405)	(1.145)
10	-2.583^a	-5.791^a
	(0.428)	(1.025)
$1[Prosocial]$	0.826^b	1.614^c
	(0.379)	(0.792)
GP score	-0.002	-0.012
	(0.007)	(0.016)
N (total/left-/right-censored)	720/—/—	720/373/24
R^2	0.109	—
$Prob > F/Prob > \chi^2$	0.000	0.000

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. Observations come from all 10 rounds of the game. Residuals are clustered at the group level (18 clusters), standard errors are computed using the leave-one-out jackknife procedure.

Chapter 3

Competition for the Greater Good: Does competition for a better access improve public goods provision?[1]

3.1 Introduction

In the Public Good Game, agents have the opportunity either to cooperate, by contributing to a public good, or to free-ride. This game makes salient the conflict - inherent to every social dilemma (Olson, 1965) - between individual and collective interests. This conflict leads to inefficiency: a situation in which social welfare is not maximized. One way to mitigate the underprovision of public goods is to give agents incentives to contribute to the public good. Different mechanisms have been tested so far (for a review, see Chaudhuri, 2011).

In this paper, I investigate in the laboratory the effects of *within-group* competition on contributions to the public good.[2] In the incentivized Rank Order Tournaments, agents compete - through their individual contribution to the public good - for a higher return

[1] This chapter is single-authored.

[2] Since the pioneering work of Lazear and Rosen (1981), economists know that one way to incite agents to provide effort is through contest. Many experiments have implemented contest in the laboratory (e.g. Bull et al., 1987; Niederle and Vesterlund, 2007) or in the field (e.g. Erev et al., 1993) and have provided

of the public good, in others words a higher Marginal Per Capita Return (hereafter MPCR). The rank in the competition - and therefore the MPCR - depends on how one's contribution ranks within the group. The aim of these mechanisms is to encourage agents to contribute to the public goods by giving them (i) a monetary incentive to contribute and by (ii) stimulating their competitive spirit.

In natural settings, an agent's return of a public good may depend on her effort provided. As already mentioned by Dawes et al. (1986), this logic exists in political or union elections. Most often, lobbyists fund or actively support candidates in order to benefit from future policies. The most important a donor, the more likely elected members will consider her opinion when making their policies. Every supporting citizen/worker benefits from the aid of the lobbyists because it helps their favourite candidate to be elected. In this way, fundraising campaigns can be seen as public goods in which the most important donors get a premium access, i.e. a higher return from the public good. In the same vein, Kickstarter, since its creation, has enabled to fund 160680 projects and more than USD 4.2 billion in donations were raised according to their statistics on the 4^{th} of April 2019. Crowdfunding campaigns, such as organized by Kickstarter, use a mechanism based on rewards to push agents to contribute to the public good: the higher the contributions, the better the rewards.

Articles have already investigated different forms of mechanism based on competition on public goods provision. Competition can be informative (e.g. Andreoni, 1995; Nikiforakis, 2010) such as agents get feedback about the rank of their contribution or the rank of their earnings. Competition can also be material. Agents can win a *fixed prize* through a lottery based on a Tullock contest (e.g. Morgan and Sefton, 2000; Goeree et al., 2005; Corazzini et al., 2010), an all-pay auction (e.g. Goeree et al., 2005; Corazzini et al., 2010), or a Rank Order Tournament (e.g. Dickinson and Isaac, 1998; Irlenbusch and Ruchala, 2008). Finally competition can be between two teams for a fixed prize (e.g. Rapoport and Bornstein, 1987; Rapoport et al., 1989), or for a higher MPCR (e.g. Tan and Bolle,

evidence in that direction (for a review, see Dechenaux et al., 2015). By giving a prize to the more productive agents, tournaments incite them to provide more efforts than their counterparts.

2007; Cárdenas and Mantilla, 2015). These papers find a positive effect of competition on public goods provision as long as competition is monetary incentivized.

The closest paper to this study has been written by Angelovski et al. (2017). In their paper, the authors implement for the first time a Rank Order Tournament within groups with *relative prizes* in a public good game context. Precisely, every agent benefits from a different MPCR depending on how their contribution ranks within the group. The higher the rank of the contribution, the higher the MPCR. They find that Rank Order Tournament increases contributions to the public good. In order to provide new insights on the effects of competition within a group, I extend this experiment.

In contrast to Angelovski et al. (2017), I assume that Rank Order Tournaments are intertwined with inequalities. In their Rank Order Tournament, in case of ties, the prize is shared between tied members, i.e. equal contributions lead to equal payoffs. In the present paper, in the incentivized Rank Order Tournaments, MPCRs are randomly assigned with equal chances for every tied member.[3] Agents who provide *ex ante* the same effort do not get the same *ex post* payoff in my experiment. My assumption is that the inequalities caused by the incentivized Rank Order Tournaments can mitigate the positive effect of monetary incentives.

I also run two additional treatments. In numerous situations, there is only a single premium member, i.e. every agent but one gets the same return. One can think about the "Most Valuable Player" award in sport. From a theoretical point of view, this new treatment is a *Single-Relative-Prize* Rank Order Tournament, when the original one can be seen as a *Multiple-Relative-Prize* Rank Order Tournament. These two treatments propose a different trade-off between risk and rewards. In the Single Prize Rank Order Tournament, only the top contributor in the group gets a high MPCR: agents have a lower probability to have a higher MPCR, but this MPCR is higher than in the Multiple Prize Rank Order Tournament. Importantly, this treatment also exacerbates the potential inequalities in

[3]This choice can be seen as an imperfect scrutiny of the central authority. Between several players who exert the same level effort, the central authority observes every effort with a negligible bias - such as it certainly does not affect the ranking of the agents who exert a different level of effort - that leads to a ranking with no ties.

ex post payoffs. These two treatments are compared to a Rank Order Tournament with no monetary prize. In this treatment, agents get the same MPCR whatever the rank of their contribution. This game is similar to the standard linear Public Good Game with additional information about the rank of the contributions of every group member. This treatment allows me to study if incentivized Rank Order Tournament triggers an increase in efficiency with respect to the standard way to privately provide public goods.[4]

The aggregated return of the public good (i.e. the sum of MPCR) is kept constant across treatments, and every treatment maintains the social dilemma paradigm with a null provision of the public good as a Nash Equilibrium. Theoretically, I show that in the Multiple Prize Rank Order Tournament and in the Single Prize Rank Order Tournament, there is a large set of other group members' contributions for which the best response of a self-interested and rational agent is to contribute a non null amount. In these treatments, if agents expect that other group members will contribute a positive amount, their best response is to contribute a positive amount to maximize their payoff in more than 99.86% of the cases. In the No-Prize Rank Order Tournament, the best response is to contribute nothing to the public good whatever the beliefs about other group members contributions. My research hypothesis is that incentivized Rank Order Tournaments will lead to higher contributions in comparison to the No Prize Rank Order Tournament. I also compute the best response of an inequality averse agent across treatments. In this case, monetary incentives can backfire. Specially, the Single Prize Rank Order Tournament can be less efficient than the Multiple Prize Rank Order Tournament because of the potential inequalities caused by this treatment.

In order to test these research hypotheses, I develop a laboratory experiment. This method allows me to have a high control on the task, maintaining homogeneous the cost of effort and the endowment of every agent, and presenting the same set of choices for every agent. I find mixed evidence. Regarding efficiency, the Multiple Prize Rank

[4] I do not choose to run a standard Public Good Game for two reasons. First, I assume that incentivzed Rank Order Tournament may have two effects: a monetary effect and a image effect. I control for this image effect by introducing Rank Order Tournament in the standard mechanism. Second, this choice allows me to keep the instructions constant across treatments. It limits noise due to difference in comprehension between treatments.

Order Tournament leads to higher aggregated contributions than the No Prize Rank Order Tournament when considering the fifteen periods, but aggregated contributions are not significantly different in the Single Prize Rank Order Tournament with respect to the No Prize Rank Order Tournament. Regarding inequalities, even if Rank Order Tournaments imply inequalities in MPCR, I find that inequalities in payoffs are not different in the Multiple Prize Rank Order Tournament with respect to the No Prize Rank Order Tournament. The Single Prize Rank Order Tournament triggers large inequalities in payoffs. Regarding the effect of time, contributions decrease over time.
I additionally compare the two incentivized Rank Order Tournaments to two control conditions in which the rank of the agents is randomly attributed and is independent from individual contributions to the public good. I do that for two reasons. First, the difference between the No-Prize Rank Order Tournament and the incentivized Rank Order Tournaments may be due to uncertainty or by heterogeneity in MPCR. I reject this assumption by finding no difference in efficiency between the No-Prize Rank Order Tournament and the two controls. Second, I compare public good games in which prizes are randomly attributed and the incentivized Rank Order Tournaments. I find that incentivized Rank Order Tournaments outperform a situation with randomly attributed premium positions only when there is a single prize.

3.2 Related literature

In this section, I first present the articles studying competition as a way to improve public goods provision and then I distinguish this study from the article of Angelovski et al. (2017).

3.2.1 Competition mechanism

Competition in the laboratory is most often centralized - a central authority observes individual or groups contributions and rewards the winning player or the winning team. Numerous mechanisms, for example, incite agents to contribute by rewarding the top contributor. Rewards can be fixed prizes, perceived as premiums. In Dickinson and Isaac (1998), as agents are heterogeneously endowed, the authors study the effects of a reward that is attributed either to the relative top contributor (i.e. the subject with the higher share of endowment contributed) or to the absolute top contributor. They find that the two treatments with competition outperform the standard Voluntary Contribution Mechanism (hereafter VCM). Furthermore, the gain in contributions is higher than the cost of the prize such as these mechanisms can be self-funded.

Competition between teams may also lead to an increase in cooperation. Such topic has been carefully studied since the seminal paper of Rapoport and Bornstein (1987). The authors created the Intergroup Public Good in which two teams - through the sum of contributions - compete for a prize. The losing team gets nothing while the winner team gets the prize. In case of tied contributions, teams share the prize. Contributions are costly such as the Pareto dominant situation is that both teams contribute nothing and share the prize. This game has been tested in Bornstein and Rapoport (1988); Rapoport et al. (1989); Bornstein et al. (1989).The authors find that contributions increase in presence of competition and that communication also increases competition and therefore contributions. Finally, with a variation of the game, the Intergroup Prisoner's Dilemma, Bornstein and Erev (1994) show that competition motivates subjects to contribute. In a field experiment, Erev et al. (1993) investigate the level of efficiency obtained after the implementation of three incentives schemes. In this experiment, four subjects have to gather oranges and are paid either depending on the performance of the group (TEAM), on their own performance (PERSONAL) or depending on their relative performance within the group (COMPETITION). Precisely, in the last treatment, the two best contributors receive a bonus payment when the two lower contributors receive no bonus. They find that COMPETITION and PERSONAL treatments outperform the TEAM treatment and perform equally well. Other games, based on VCMs, exist with between-groups competition. In Gunnthorsdottir and Rapoport (2006); Burton-Chellew et al. (2010), groups, through their aggregated contributions, compete for a fixed prize; in Tan and Bolle (2007); Cárdenas and Mantilla (2015), they compete for a higher MPCR; in Puurtinen and Mappes (2009); Markussen et al. (2014), they compete for positive money transfers from other agents and in Reuben and Tyran (2010) they compete to avoid a fee. In all these articles, competition, as long as it is monetary incentivized, promotes contributions.[5]

Other kinds of mechanism based on within-group contributions' ranking have been tested. Morgan (2000) first shows theoretically that Tullock fixed-prize lotteries should improve contributions to the public good. Morgan and Sefton (2000) test it in the laboratory and confirm the theoretical result. In their experiment, agents contribute by purchasing tickets and have a proportional chance to win the fixed prize. They find that the net quantity of money due to the sales of tickets bought balances the prize. Goeree et al. (2005) have shown that using all-pay auctions to fund public goods leads to higher contributions than using lotteries or winner-pay auctions. This study has been extended by Corazzini et al. (2010) with agents with heterogeneous endowment. They compare all-pay auctions and Tullock contest to a VCM with a heterogeneous population. They find that lottery performs slightly better than all-pay auctions and that both mechanisms outperform the VCM. In all treatments, they find that subjects with a high endowment contribute more, and that this effect is even more important with a fixed prize. In Faravelli and Stanca (2014), the authors find that lotteries and all-pay auctions are both equally efficient to raise funds. In a heterogeneous environment, Faravelli and Stanca (2012) show that single-prize all-pay auctions perform better than multiple-prize all-pay auctions but that the participation is higher with multiple prizes. Single-prize auctions lead to an increase in contributions of high endowed agents while multiple-prize auctions do not trigger more contributions of low endowed agents. In Croson et al. (2015), the agent with the lowest contribution is systematically excluded from the public good - in other words, her MPCR for the round is equal to 0. The authors

[5]What must be noticed is the change in equilibrium depending on the prize. A fixed prize associated with a lottery (e.g. Burton-Chellew et al., 2010; Gunnthorsdottir and Rapoport, 2006) leads to a situation with positive contributions as a Nash Equilibrium. In Cárdenas and Mantilla (2015) and in Reuben and Tyran (2010), there is a Pareto-dominant Equilibrium.

show that excludability is associated with a large increase in contributions in the long run.

Finally, competition with no monetary rewards exists. In Cabrera et al. (2013), agents are grouped according to their previous contribution level. The top contributors are in the "first league" when the low contributors are in the "second league". They find that this mechanism increases contribution in the two leagues with respect to a standard VCM. In Nikiforakis (2010), agents have a detailed feedback either about every group member's earnings or about every group member's contribution. Subjects tend to be less cooperative when they have information about earnings in comparison to the situation in which they have information about contributions. Andreoni (1995) tests, among others, two treatments: one standard VCM and one standard VCM with feedback about the rank of earnings and finally find a negative effect of feedback on contributions.

Taking together, this literature suggests that competition leads to higher efficiency than the standard VCM. Two effects can explain this result: competition can lead to monetary rewards and therefore give an incentive to subjects to contribute, or competition can stimulate contributions through image.

3.2.2 This study

To the best of my knowledge, Angelovski et al. (2017) was the first to study *within-group* competition with relative rewards.[6] They implement a mechanism - a Multiple Prize Rank Order Tournament - such as the rank of the contribution in a round impacts the MPCR an agent gets for this round. The top contributor - the group member with the highest contribution - gets a MPCR equals to 0.65, the second best contributor gets a

[6] Recently, Colasante et al. (2019) investigate the effect of within-group competition. The authors study contributions to the public good in three environments: two Rank Order Tournaments and a standard Public Good Game. They vary the risk in the two Rank Order Tournaments by modifying the variation in MPCR. As in Angelovski et al. (2017), the prize is shared between subjects who contribute the same amount. They find that (i) Rank Order Tournaments increase contributions to the public good with respect to the standard mechanism, (ii) that the riskier treatment, the treatment with the largest variation in *ex post* MPCRs, leads to the higher level of contributions. This paper (i) does not use the same calibration than us, (ii) does not focus their theoretical framework on other-regarding preferences, (iii) uses a rule of "sharing the prize" in case of tied contributions, (iiii) does not consider in their baseline treatment a Rank Order Tournament framework.

MPCR equals to 0.55, the third one gets a MPCR equals to 0.45 and finally the last one gets a MPCR equals to 0.35. They find that within-group competition increases the private provision of public goods.

Using the same calibration, I replicate their Multiple Prize Rank Order Tournament treatment with an important difference. In the original Rank Order Tournament, in case of tied contributions, an average value of the MPCR is applied to every tied member. In my experiment, in the incentivized Rank Order Tournaments, MPCRs are randomly assigned with equal chances for every tied member. In these treatments, if agents provide *ex ante* the same effort, they will not have the same *ex post* payoff. My assumption is that the inequalities caused by the incentivized Rank Order Tournaments can mitigate the positive effect of monetary incentives.

I also implement a new mechanism: a Single Prize Rank Order Tournament. In this mechanism, there is a unique prize. Only the top contributor gets a premium access associated with a MPCR equals to 0.95. Every other agents gets a return of 0.35. I develop this mechanism to study the trade-off between risk and rewards: In SP-ROT, members have a smaller chance to win the prize, but the prize is more rewarding. Note that, two contributors cannot reach a cooperation equilibrium in the Single Prize Rank Order Tournament treatment in a one shot.[7] This feature is important and may explain why agents contribute in Multiple Prize Rank Order Tournament. Additionally, this treatment is likely to triggers larger inequalities with respect to the Multiple Prize Rank Order Tournament and may lead to lower contributions for inequality averse agents. I discuss this question in Section 3.3.3.2.

I also differentiate from Angelovski et al. (2017) in the comparison I choose to make. I compare the two treatments not only to two control conditions in which ranks are randomly attributed but also to the standard VCM with a Rank Order Tournament with

[7] In Angelovski et al. (2017), if exactly two agents contribute their full endowment, they have a final payoff of 60 tokens, higher than their initial endowment of 50 tokens. In my version of the MP-ROT, in the same situation, the payoff of the highest contributor who has been randomly selected is equal to 65 tokens, when the other contributor gets a final payoff of 55 tokens. In the Single Prize Rank Order Tournament treatment I propose to implement, in the same situation, the two contributors would have a payoff of 80 tokens and 40 tokens, such as one contributor would have lost 10 tokens in comparison to her initial endowment.

no reward (called No Prize Rank Order Tournament) in order to see how efficient are the incentivized Rank Order Tournaments in comparison to the standard one.[8]

3.3 Games, Calibration and Predictions

3.3.1 Rank Order Tournaments

In the standard VCM, N subjects are endowed with e tokens and have the possibility to contribute a part c, between 0 and e, of their endowment to the public good. Every token contributed to the public good yields a Marginal Per Capita Return of α token to every group member. Every token not contributed by an agent is saved on a private account and yields exactly one token to this agent. In this game, the Nash Equilibrium is a situation in which no agents contribute to the public good (because the return of the public good α is lower than return of the private account: $\alpha < 1$) while social welfare is maximized when every agent contributes her whole endowment to the public good. Decisions about the amount to contribute are made simultaneously and privately, such as agents ignore the choice made by their counterparts. The payoff function of agent i can be written as follows:

$$\Pi_i(c_i) = (e - c_i) + \alpha \sum_{k=1}^{n} c_k \tag{3.1}$$

In Rank Order Tournaments, agents' contributions are ranked from the highest (which ranks 1) to the lowest (which ranks N). The payoff system described below is common knowledge. Agents know that the top contributor will receive a MPCR equals to α^1, the second best contributor will receive a MPCR equals to $\alpha^2, \ldots$, and the bottom contributor will receive a MPCR equals to α^N. In case of tied contributions, α is randomly attributed between the tied contributors. Finally, the payoff function of agent i is the following:

[8]The control condition chosen by Angelovski et al. (2017) was in line with their motivating example: in their paper, the authors propose as an illustration for their mechanism the organ donation system, in which the recipient is randomly chosen.

$$\Pi_i(c_i) = \begin{cases} (e-c_i) + \alpha^1 \sum_{k=1}^{N} c_k & \text{if } c_i = \max(c_1, c_2, ..., c_N) \text{ and } \forall j \neq i | c_j = c_i \text{ ; } \epsilon_i = \max\limits_{k=\{i;j\}} \{e_k\} \\ ... \\ (e-c_i) + \alpha^N \sum_{k=1}^{N} c_k & \text{if } c_i = \min(c_1, c_2, ..., c_N) \text{ and } \forall j \neq i | c_j = c_i \text{ ; } \epsilon_i = \min\limits_{k=\{i;j\}} \{e_k\} \end{cases} \tag{3.2}$$

$(\alpha^1, ..., \alpha^N)$ take different values depending on the treatment. In the No Prize Rank Order Tournament (hereafter NP-ROT), the MPCR does not depend on the rank of the contribution: $\alpha^1 = ... = \alpha^N$. In the Single Prize Rank Order Tournament (hereafter SP-ROT), $\alpha^1 > \alpha^2 = ... = \alpha^N$. The top contributor gets a high MPCR, and every other agent gets the same MPCR. In the Multiple Prize Rank Order Tournament (hereafter MP-ROT), agents know that $\alpha^1 > \alpha^2 > ... > \alpha^N$. $(\alpha^1, ..., \alpha^N)$ are chosen across treatments such that the aggregated return of the public good (i.e. the sum of α) is identical in every treatment and in order to maintain a social dilemma.

3.3.2 Control Conditions

One may wonder if *ex post* inequalities in MPCR and imperfect information about the value of the MPCR may explain differences in results other than those attributed to Rank Order Tournaments. In order to deal with these points, I run two additional control conditions: a Single-Prize Control (hereafter SP-CTL) and a Multiple-Prize Control (hereafter MP-CTL). In these control conditions, agents have to choose how many tokens they want to contribute to the public good. They know that a rank - between 1 and N - will be randomly attributed to each of them after that they make their decision. Two agents cannot be assigned the same rank. In SP-CTL, the agent with rank 1 will benefit from a MPCR equals to α^1 and every other agents will benefit from the same MPCR, lower than α^1: $\alpha^1 > \alpha^2 = ... = \alpha^N$. The values $(\alpha^1, ..., \alpha^N)$ are known by the subjects and are equal to the MPCR values in SP-ROT. In MP-CTL, an agent with the rank i will have a MPCR equals to α^i. Agents know the values of $(\alpha^1, ..., \alpha^N)$. In MP-CTL, $(\alpha^1,...,\alpha^N)$ are the same than in MP-ROT.

3.3.3 Predictions

3.3.3.1 Predictions with no other-regarding preferences

Table 3.1 – Calibration of the MPCR depending on the treatment

Treatments	MP-ROT	SP-ROT	NP-ROT	MP-CTL	SP-CTL
Value of α	$\alpha^1 = 0.65$	$\alpha^1 = 0.95$	$\alpha^1 = 0.5$	$\alpha^1 = 0.65$	$\alpha^1 = 0.95$
	$\alpha^2 = 0.55$	$\alpha^2 = 0.35$	$\alpha^2 = 0.5$	$\alpha^2 = 0.55$	$\alpha^2 = 0.35$
	$\alpha^3 = 0.45$	$\alpha^3 = 0.35$	$\alpha^3 = 0.5$	$\alpha^3 = 0.45$	$\alpha^3 = 0.35$
	$\alpha^4 = 0.35$	$\alpha^4 = 0.35$	$\alpha^4 = 0.5$	$\alpha^4 = 0.35$	$\alpha^4 = 0.35$

Note. α^1, α^2, α^3, α^4 represent the respective MPCR of the agent who ranks 1, 2, 3, and 4. In the Rank Order Tournament treatments (-ROT), the rank of an agent depends on how her contribution ranks within the group. In the control conditions (-CTL), the rank is randomly attributed.

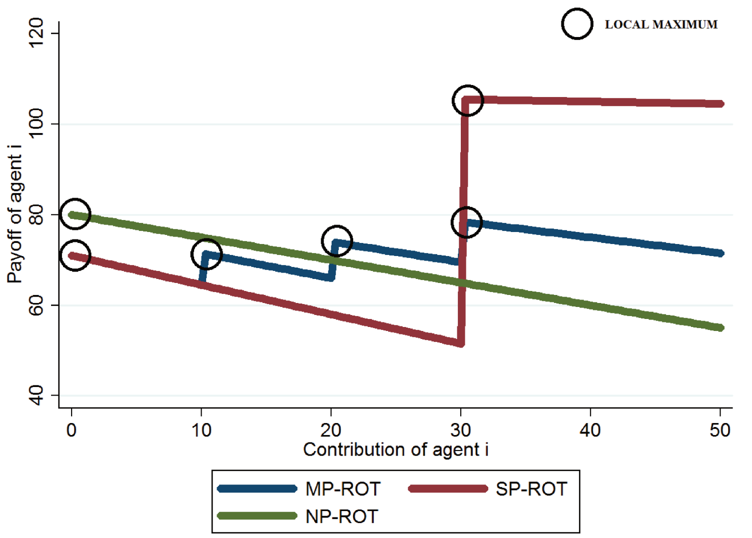
In the present experiment, I use the calibration (which is common knowledge) presented in Table 3.1. Each group is composed of four agents endowed with 50 ECU.[9] In every treatment, every token contributed to the public good is multiplied by two and redistributed. The redistribution rule differs across treatments. Consequently, *ex post* payoffs may be different across treatments for the same set of contributions.

In NP-ROT, MP-CTL and SP-CTL, the payoff function of agent i is decreasing in c_i whatever the average contribution value of the other group members ($\bar{c}$). In other words, the more an agent contributes to the public good *ceteris paribus*, the less her payoff. It is not necessarily the case in SP-ROT and in MP-ROT. I depict, for instance, the payoff function of agent i depending on her contribution in every Rank Order Tournament treatment in Figure 3.1 when one group member contributes 10 tokens, another group member contributes 20 tokens and the last group member contributes 30 tokens to the public good.

In SP-ROT, given the value of α^1 and α^i ($\forall i \neq 1$), the sum of other group members contributions and the highest contribution among other group members, there potentially exist up to two local maxima in the payoff function (Equation 3.2), namely $c_i^* = 0$ and

[9] The calibration chosen for NP-ROT has been already used in different articles (e.g. Andreoni, 1990; Buckley and Croson, 2006). The calibration chosen for MP-ROT is the same as in Angelovski et al. (2017). The calibration chosen for SP-ROT is such as the low MPCR is identical as in MP-ROT. In SP-ROT and in MP-ROT, agents have the same interest to free-ride.

Figure 3.1 – Example of agent *i* payoff function depending on her contribution: the case in which the three other group members contribute respectively ten tokens, twenty tokens and thirty tokens in MP-ROT, SP-ROT and NP-ROT



$c_i^{**} = \max_{l \neq i}(c_l) + 1$. Specially, when the benefit of being the top contributor is higher than the cost of the contribution, the payoff function is maximized when the agent contributes such as she becomes the top contributor.[10] In MP-ROT, there potentially exist up to 4 local maxima. Every agent has the possibility to rank 1, 2 or 3 and to benefit from α^1, α^2 or from α^3. Therefore there is a new reason to contribute. Agents should no longer contribute only for other-regarding motives (i.e. increasing others' payoff) but also for a monetary motive (i.e. maximizing their own payoff).[11] Following this assessment, I assume that contributions should be higher in SP-ROT and in MP-ROT than in NP-ROT, MP-CTL and SP-CTL.

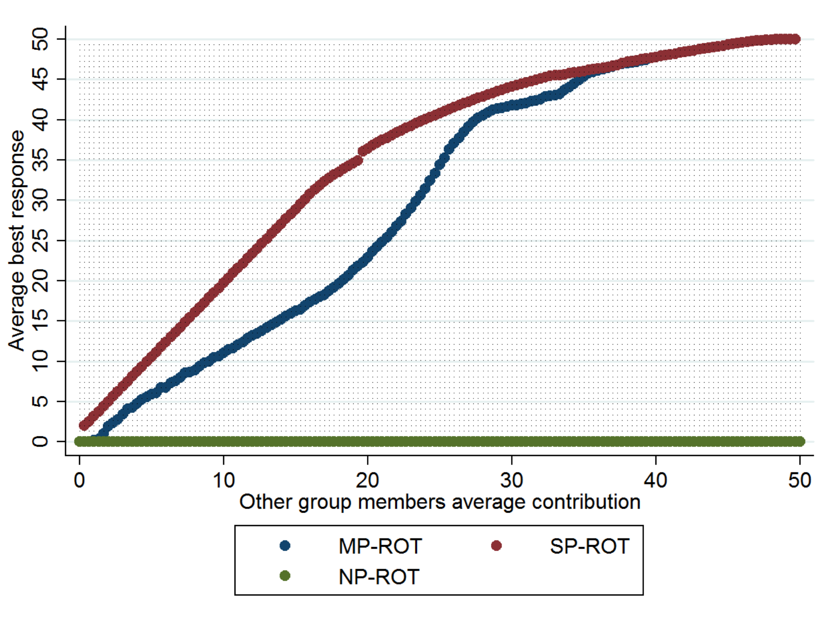
To derive predictions about SP-ROT and MP-ROT, I compute the best response function of a rational and self-interested agent in both treatments. In Figure 3.2, I show the average best response function of this agent depending on the average contribution of

[10] With the calibration used in this paper, it is always true for a set of contribution $E = \{(c_1, c_2, c_3) \in [|0;49|]^3 | \exists l \in \{1;...3\}, c_l > 0\}$.

[11] Competition could also backfire. One can imagine a situation in which an agent contributes to the public good when there is no monetary incentives for other-regarding motives and that stops contributing to the public good when a competition for a premium access is available. Competition can deter prosocial agents from contributing to the public good.

other group members.[12] I observe that the average best responses are lower in MP-ROT than in SP-ROT. This result can be easily explained. In MP-ROT, you may benefit to not rank 1, because the cost of ranking 1 is larger than the benefit of ranking 2, 3 or 4 (it happens in 22.77% of the cases). In SP-ROT, the best response is the contribution associated to rank 1 in more than 99.7% of the cases. A positive contribution is the best response in more than 99.93% of the cases (132563 out of 132651 of the possible sets of contributions) in MP-ROT and in more than 99.86% of the cases (132475 out of 132651 of the possible sets of contributions) in SP-ROT.

Figure 3.2 – Average best responses in MP-ROT, in SP-ROT and in NP-ROT depending on the other group members average contribution



Note that, in every treatment, the best response of a rational and self-interested agents is to contribute nothing when every other group member contributes their whole endow-

[12]In this project, I do not work only with the average contribution of other group members because this average value does not give the contribution of every agent and therefore their rank. Instead, I work with the set of contributions. I compute every combination of (c_1, c_2, c_3) and determine for each of the 132651 combinations the best response depending on the contributions and the rank associated in the two treatments. I then compute an average best response for each average value of other group members contribution.

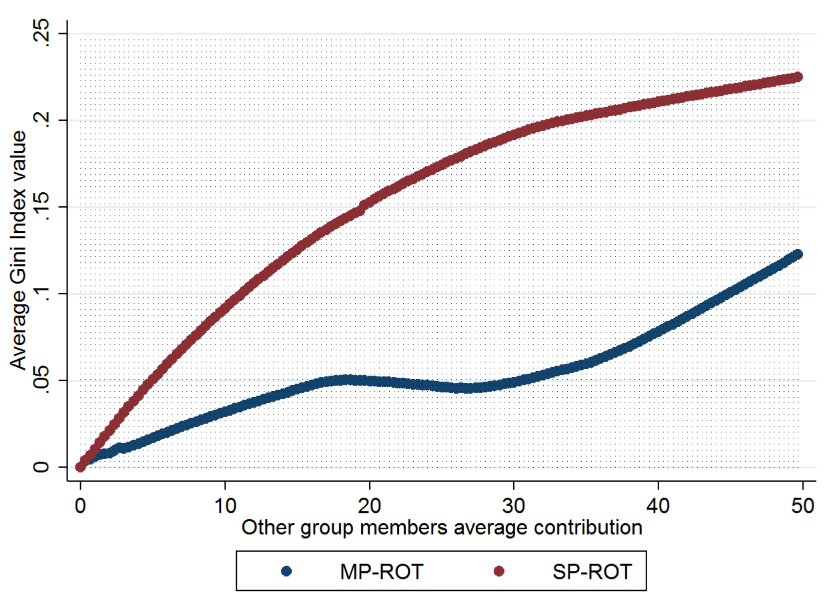
ment. It leads me to the following research hypothesis.

Research hypothesis - Self-Interested: If agents expect positive contributions from other group members, the ranking of contributions should be:
SP-ROT > MP-ROT > NP-ROT = SP-CTL = MP-CTL.

3.3.3.2 Theoretical predictions using ERC framework (Bolton and Ockenfels, 2000)

In Figure 3.3, I plot the average GINI index values when a rational and self-interested agent plays her best response. Best responses are associated with larger inequalities in SP-ROT than in MP-ROT. I assume that the inequalities driven by the different treatments are likely to influence the contribution behaviour.[13]

Figure 3.3 – Average GINI index value associated with average best response of a rational and self-interest agent in MP-ROT and in SP-ROT



[13] Another valid approach would have been to focus on an agent's risk preferences. No model linking other-regarding preferences and risk preferences is unanimously approved. Since (i) agents evolve in a group and (ii) a standard way of explaining contributions to the public good game is based on other-regarding preferences, I have favoured an approach based on inequality aversion.

In the Equality, Reciprocity and Competition (ERC) framework, built by Bolton and Ockenfels (2000), the utility function of an agent depends not only on her payoff but also on the relative inequalities. Utility increases when π_i (i's payoff) increases but decreases as the distance between π_i and $\frac{\pi_i}{\Pi}$ (Π represents the sum of payoffs within the group) increases. The utility function can be written as follows:

$$U_i = V_i\left(\pi_i, \frac{\pi_i}{\Pi}\right) \tag{3.3}$$

In the specific context of a four-player VCM, I adapt the method developed by Fischbacher et al. (2014) and used in Théroude and Zylbersztejn (2019). I use the following additively separable utility function:

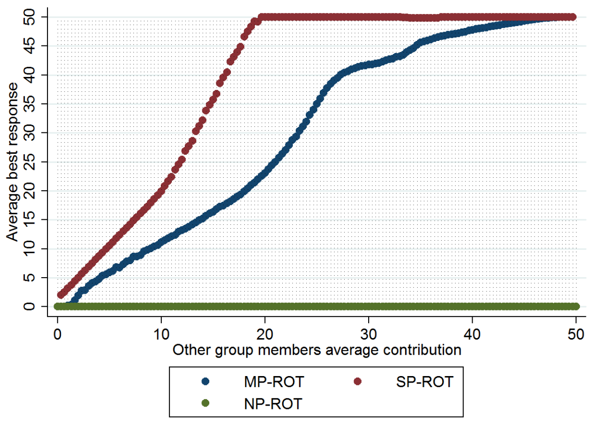
$$U_i(\pi_i) = \pi_i - \nu_i \times \left(\frac{\pi_i}{\pi_i + \sum_{j \neq i} \pi_j} - \frac{1}{4}\right)^2 \tag{3.4}$$

with π_i and π_j defined in Equation 3.2. ν_i represents a measure of inequality aversion. Note that, in this model, agents are as averse to disadvantageous inequalities as to advantageous inequalities.

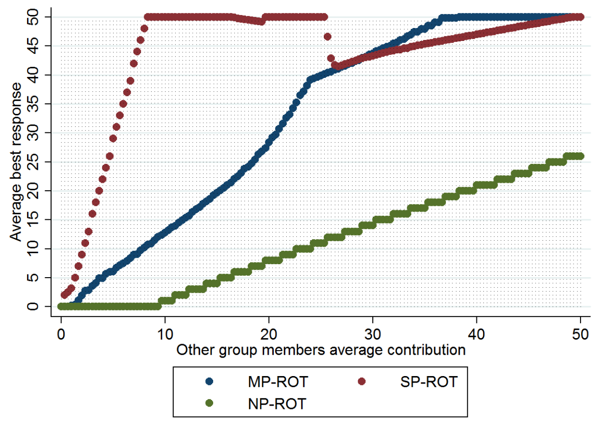
The decision maker considers every possible set of other group members contributions. She then is able to find the contribution that maximizes her utility for every set of contributions. In simulations, I derive her average best response for every other group members average contribution using three levels of risk aversion: $\nu_i = 250$, $\nu_i = 2500$ and $\nu_i = 25000$. I plot these simulations in Figure 3.4.

What I observe is that inequality aversion leads to several effects. First of all, in NP-ROT, when an agent's inequality aversion goes beyond a threshold, her average best response increases when other average group members contribution increases. This agent does not accept to be richer than the other group members and therefore contributes to the public good. Second, in incentivized Rank Order Tournaments, agents with a low level of inequality aversion contribute more than self-interested agents. It is explained by the fact that being the top contributor leads to too large inequalities. Consequently, her best response is to overcontribute (i.e. to contribute a higher amount than what maximize

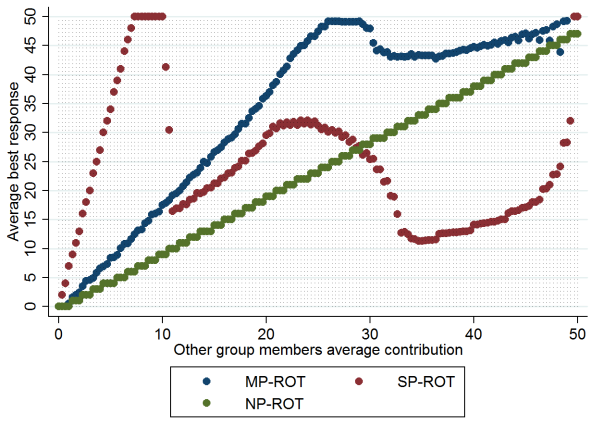
Figure 3.4 – Average best responses of an inequality averse agent in MP-ROT, in SP-ROT and in NP-ROT depending on other group members average contribution



(i) $\nu = 250$



(ii) $\nu = 2500$



(iii) $\nu = 25000$

her payoff) in order to decrease inequalities. However, beyond a threshold, inequality aversion decreases the average best response. This effect is even more important in SP-ROT in which inequalities can be important for a high best response. For instance, when $\nu = 25000$, there is a large number of other group members average contribution for which the average best response is equal or higher in NP-ROT than in SP-ROT. Even if MP-ROT leads to inequalities in MPCR, average best responses are higher in MP-ROT than in NP-ROT because the monetary gain is higher than the loss due to inequalities.[14] Finally, given the theoretical predictions I compute and the results of Angelovski et al. (2017), I assume that there will be higher contributions in the Rank Order Tournaments with relative rewards than in the NP-ROT and than in the two control conditions. Following the result of Fischbacher et al. (2014), I also assume that a competitive risk - a risk such as it certainly creates *ex post* inequalities in MPCRs - is likely to trigger lower contributions in the control conditions with respect to NP-ROT. Regarding MP-ROT and SP-ROT, two kinds of evidence go one against another with respect to the contributions. If I consider a self-interested agent, contributions should be higher in SP-ROT than in MP-ROT. However, when introducing other-regarding preferences, this statement may not hold because of the inequalities present in SP-ROT.

Research hypothesis 2 - including other-regarding preferences: The ranking of contributions should be: MP-ROT $\stackrel{?}{=}$ SP-ROT > NP-ROT $>$ MP-CTL $\geq$ SP-CTL.

3.4 Experimental Procedures

Eleven sessions were run between June and December 2018 in the GATE-Lab. Subjects (49% males, average age 21.25), who had registered in hroot Bock et al. (2014), were recruited. 56 subjects (in 14 groups) participated in MP-ROT, 36 subjects (in 9 groups) participated in SP-ROT and 40 subjects participated (in 10 groups) in NP-ROT, MP-CTL and SP-CTL. All experimental treatments were computerized using z-Tree (Fischbacher, 2007). Experiments lasted between one hour and one hour and half. The average payoff was €15.8. This payoff included a €5 show-up fee and the payoff earned during the experiment.

[14]Average best response is an indicator. The proportion of best response equal or higher in a treatment with respect to another is a complementary indicator. When $\nu = 25000$, best responses are equal or higher in MP-ROT than in SP-ROT in 89.5% of the possible sets of contributions. Best responses are equal or higher in NP-ROT than in SP-ROT in 45.71% of the possible sets of contributions. Best responses are equal or higher in MP-ROT than in NP-ROT in 99.13% of the possible sets of contributions.

I invited only subjects who had never participated in Public Good Games experiments in order to avoid observing behaviours contaminated by previous experiments. Subjects came to the laboratory and were randomly assigned to a computer. Instructions were first read aloud.[15] Then subjects read them alone, quietly and had the possibility to privately ask any question to the experimenter. The instructions were neutrally framed: every agent had the possibility to invest in a common group account. When they finished to read the instructions, they were asked to fill an understanding questionnaire about the experiment. Once every subject completed the questionnaire, the experiment began.

The experiment consisted on a unique fifteen-period game. The game differed across treatments (either MP-ROT, SP-ROT, NP-ROT, MP-CTL or SP-CTL). Treatments were introduced in a between-subjects manner. At the beginning of the game, subjects were randomly matched in groups of four. Agents interacted with the same group during the whole experiment (this was common knowledge). The partner matching protocol allowed subjects to have information about other subjects' choices and to adapt their strategy over time. In every period, agents had to choose their contribution to the public good. Their contribution level should be an integer value. They had the possibility to enter four virtual contributions in a simulator in order to know their potential payoff associated with such contributions. At the end of each period, subjects received an individual feedback reminding them their level of contribution, giving them their rank, their MPCR, and detailing their potential gain for this period separating earnings from the public account and from the private account. Additionally, they were informed about the individual contribution of every group member and the rank associated to each contribution.[16] Contributions were anonymous. One period was randomly and independently selected to determine every agent final payoff.

[15]Instructions translated in English are provided in Appendix A.2.

[16]I assume that being informed about individual contribution may lead to more efficiency in this framework. Indeed, agents know what are the contributions and may react accordingly. It may allow for more coordination even in a VCM. Sell and Wilson (1991) find that feedback at the individual level increases efficiency when Croson (2001) and Weimann (1994) find no significant differences. Moreover, for an external validity concern, such feedback may be obtained in a employee of the month contest.

At the end of the game, after knowing their final earnings, agents were asked to complete a small questionnaire with Likert scales about their understanding of the game, the clarity of the instructions, the fairness of the mechanism they coped with and how nice they thought it was to contribute to the public good.

3.5 Results

In this section, I present the results of the experiment, focusing on three different aspects: efficiency, inequalities and sustainability.[17] These three aspects of the game are important for the decision maker. Do agents contribute? Do mechanisms generate inequalities? Do contributions decay over time?

3.5.1 Efficiency

Table 3.2 – Descriptive statistics: Contributions by treatment

Dep. variable:	Contributions over the fifteen periods				
			Quartiles		
	Mean	Standard Deviation	25%	50%	75%
MP-ROT	26.914	20.073	5.5	27	50
SP-ROT	23.383	22.983	0	18.5	50
NP-ROT	19.39	18.681	0	15	35
MP-CTL	22.05	14.454	10	20	30
SP-CTL	16.123	16.131	2	10	25

I measure efficiency as the average contribution within groups. I compute in Table 3.2 the mean contribution, the standard deviation and the quartile contributions in each treatment. Looking at average contributions, I observe that the efficiency ranking is slightly different from the one of my first research hypothesis: as predicted, contributions are higher in the incentivized Rank Order Tournaments, but are higher in MP-ROT than in SP-ROT. As I provide theoretical insights predicting that contributions should be higher in the incentivized Rank Order Tournament, I use one-tailed tests in this section

[17] Additional evidence for each result is provided in Appendix A.1.

when I compare incentivized Rank Order Tournaments to the other treatments.

Result 1 - Effects of Monetary Incentives: When considering the fifteen periods, (i) I find that efficiency is higher in MP-ROT than in NP-ROT but (ii) I find no increase in efficiency in SP-ROT with respect to NP-ROT. Efficiency is not different in the two incentivized Rank Order Tournament treatments.

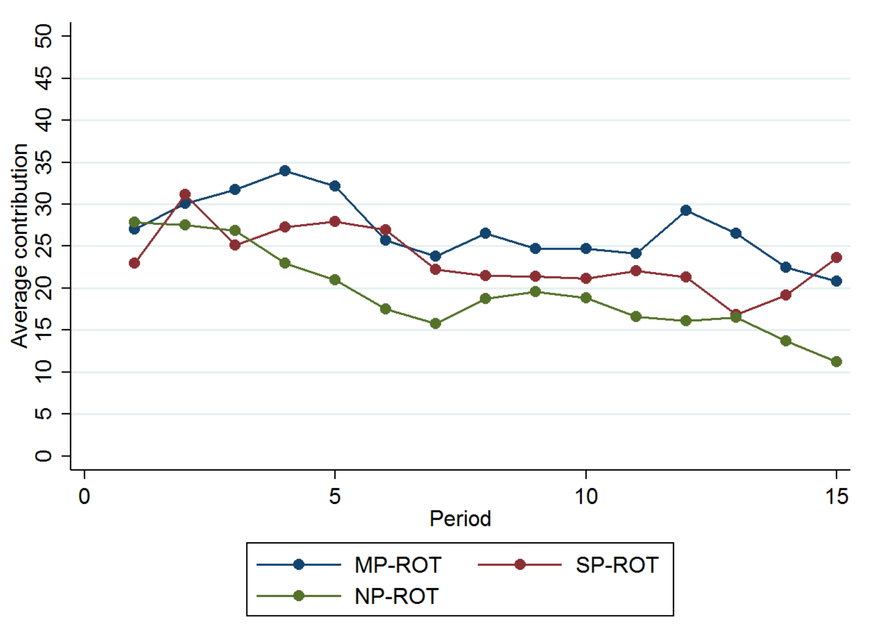
Support. At first glance, Figure 3.5 seems to indicate higher contributions in both MP-ROT and SP-ROT with respect to NP-ROT. Using pairwise comparisons based on Wilcoxon ranksum test, I reject the null hypothesis that the groups average contributions over the fifteen periods come from the same distribution when comparing MP-ROT and NP-ROT (one-tailed test, p-value = 0.051), but I do not reject the null hypothesis when comparing SP-ROT and NP-ROT (one-tailed test, p-value = 0.111). Using a Wilcoxon ranksum test, I also do not reject the null hypothesis when comparing MP-ROT and SP-ROT (two-tailed test, p-value = 0.4128). ■

One can argue that the differences in efficiency between MP-ROT and NP-ROT can be due to heterogeneity in MPCR and to uncertainty about MPCR when the agents make their decision. To tackle this question, I compare efficiency in NP-ROT to efficiency in MP-CTL and in SP-CTL. In the two control conditions, agents (i) do not know their future MPCR when they make their decision and (ii) know that there will be heterogeneity in MPCR when the public good will be provided.

Result 2 - No effect of uncertainty and heterogeneity in MPCRs When comparing NP-ROT and MP-CTL and SP-CTL, I find no differences in efficiency.

Support. I plot the average contribution per period in NP-ROT, MP-CTL and SP-CTL in Figure 3.6. Using two pairwise Wilcoxon ranksum tests, I do not reject the null hypothesis that the groups average contributions come from the same distribution when

Figure 3.5 – Average contribution over time across Rank Order Tournament Treatments

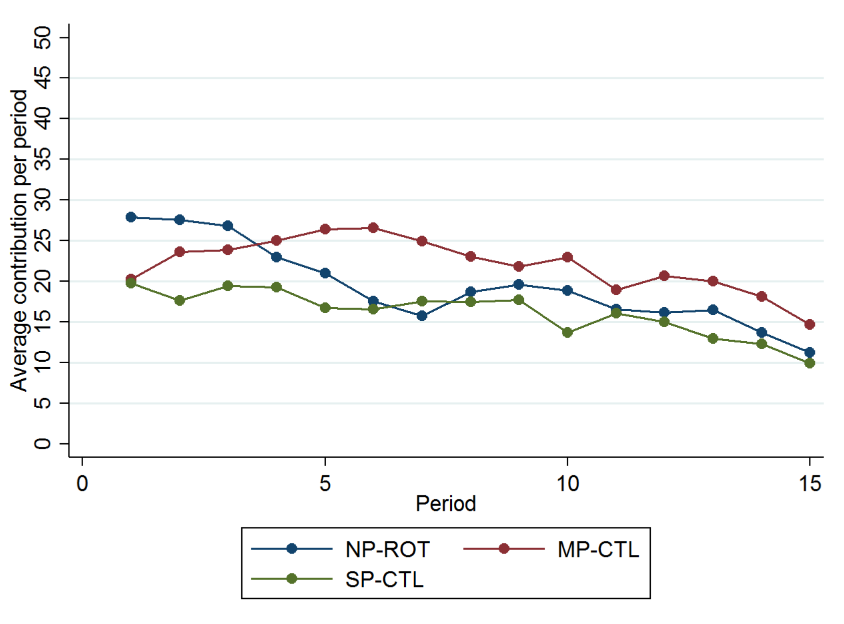


comparing NP-ROT and MP-CTL (two-tailed, p-value = 0.406) and when comparing NP-ROT and SP-CTL (two-tailed, p-value = 0.326).[18]■

This result shows that the differences observed between NP-ROT and MP-ROT is neither due to uncertainty in MPCR nor to heterogeneity in MPCR. Taking together, Result 1 and Result 2 indicate that Rank Order Tournaments with incentives may lead to an increase in public goods provision with respect to the standard mechanism when there are multiple prizes. As I consider a Rank Order Tournament with no prize, I control for the potential competitive spirit effect present in MP-ROT and in SP-ROT. The positive effect on efficiency observed in MP-ROT with respect to NP-ROT should be mainly due to the monetary rewards provided to the high contributors in MP-ROT. However, this monetary reward does not increase efficiency in SP-ROT with respect to NP-ROT. I see at least two reasons to explain this null result. First, as discussed in footnote 7, in MP-ROT, when only two agents contribute the same amount to the public good, they are better off than when they do not contribute. It is not the case in SP-ROT in a single period. Second,

[18]Interestingly, this result goes against what has been previously found in Fischbacher et al. (2014).

Figure 3.6 – Average contribution per period across treatments: NP-ROT vs MPCTL vs SPCTL

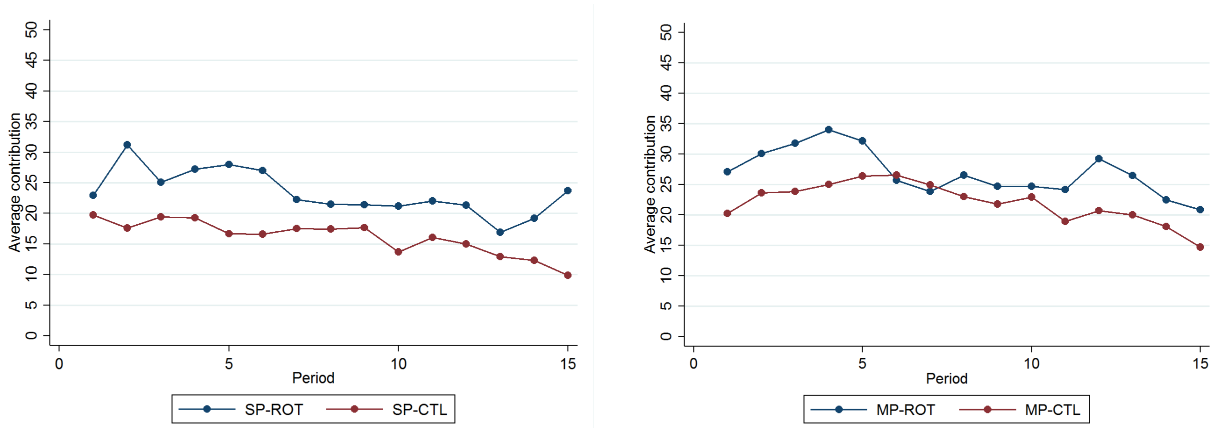


SP-ROT may lead to high inequalities because of the distribution of *ex post* MPCR. Such a question is tackled in Section 3.5.2. According to my second research hypothesis, these inequalities may decrease the contributions of highly inequality averse agents.

Result 3 - Effects of Rank Order Tournaments: When comparing Rank Order Tournament treatments with controls in which prizes are randomly attributed, I find mixed results. Efficiency is higher in SP-ROT with respect to SP-CTL but is not significantly higher in MP-ROT with respect to MP-CTL.

Support. In Figure 3.7, I plot the average contribution per period comparing SP-ROT vs SP-CTL and MP-ROT vs MP-CTL. Contributions seem higher in the Rank Order Tournament treatments. Using pairwise comparisons based on Wilcoxon ranksum test, (i) I reject the null hypothesis that the groups average contributions over the fifteen periods come from the same distribution (one-tailed test, p-value = 0.021) when comparing SP-ROT and SP-CTL and (ii) I do not reject the null hypothesis that the groups average

Figure 3.7 – Average contribution over time across environments: Rank Order Tournament treatments vs control conditions



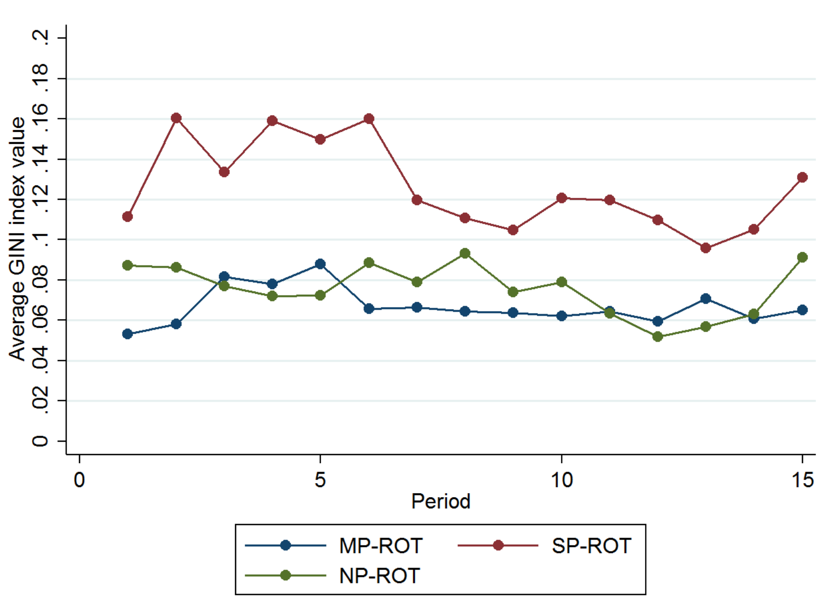
(i) SP-ROT vs SP-CTL (ii) MP-ROT vs MP-CTL

contributions over the fifteen period come from the same distribution (one-tailed test, p-value = 0.121) when comparing MP-ROT and MP-CTL. ■

At this stage, two points have to be mentioned. First, I find evidence that a Rank Order Tournament with a single prize leads to higher efficiency than a game with a randomly attributed premium access. This result indicates that Rank Order Tournament may increase public goods provision: agents contribute more when their contribution affects their probability to win the prize. However, when considering multiple prizes, I do not find any effect on efficiency of a Rank Order Tournament. This result is different from the one found by Angelovski et al. (2017). Logically, contributions in MP-ROT (mean: 26.91) are lower in my experiment than in theirs (mean: 38.5). One reason for such a difference is that agents, most likely, do not enjoy *ex post* inequalities when they *ex ante* provide the same effort. This fact holds with median contribution (median: 27 vs 50). I also observe larger standard errors in my experiment (s.e: 20.07) than in the one of Angelovski et al. (2017) (s.e: 13.8). It can also be explained by the difference in my game. Once agents reach the full contributions situation, it creates inequalities in my experiment that may lead to changes in behaviours. In their experiment, when agents reach the full contributions situation, there are no inequalities and agents are less likely to change their contribution behaviour. What is more puzzling is the behaviour in the control condition (MP-CTL). In their experiment, they observe lower contributions and lower standard errors (mean: 16.4; s.e: 11.5) than in the present paper (mean: 22.05; s.e: 14.45). To the best of my knowledge, there is no difference between my control condition and theirs. Such difference may be explained by either a different pool of subjects or by randomness.

3.5.2 Inequalities

Figure 3.8 – Average GINI Index value per period across treatments



One important concern of the policy makers lies on inequalities. Decision-makers may be uncomfortable with mechanisms that generate large inequalities. Additionally, inequalities may be detrimental because it can reduce the contribution of inequality averse agents. I investigate the level of inequalities in every treatment. In order to do so, I compute the GINI Index of each group for each period in every treatment. I present visual evidence in Figure 3.8. At first glance, inequalities seem larger in SP-ROT.

Result 4 - Inequalities: Inequalities differ across treatments. Inequalities are more important in SP-ROT.

Support. I run 3 pairwise Wilcoxon ranksum tests. I reject the null assumption that the average GINI index per group over the fifteen periods comes from the same distribution in MP-ROT and in SP-ROT (p-value = 0.005). I also reject the null assumption of the Wilcoxon ranksum when comparing SP-ROT vs NP-ROT (p-value = 0.033). I do not reject the null assumption of the Wilcoxon ranksum for the comparison between MP-ROT and NP-ROT (p-value = 0.466).■

Two explanation criteria may explain differences in GINI index. First, the environment may be by nature more unequal. Second, inequalities may be due to differences in contributions. Indeed, whatever the treatment, a null contribution within a group leads to zero inequality and, consequently, a null value of the GINI index. In order to have a proper idea about the reason of the inequalities observed in Figure 3.8, I present in Table 3.3 the relation between inequalities and efficiency for every treatment. I find that higher contributions within a group lead to higher inequalities in every treatment (Spearman's $\rho > 0.232$, p-value < 0.004). Jennrich test rejects the equality of correlation between the sum of contributions and GINI index value in the three treatments (p-value < 0.001). Using three pairwise Jennrich tests, I find that the correlation between the sum of contributions and the GINI index value is significantly different when comparing SP-ROT and MP-ROT (p-value < 0.001), when comparing MP-ROT and SP-ROT (p-value < 0.001) and when comparing SP-ROT and NP-ROT (p-value < 0.001). I conclude that higher contributions lead to higher inequalities in SP-ROT with respect to MP-ROT. This effect may explain Result 1: agents may reduce their contributions to avoid large inequalities. Such an effect goes in the same direction that the theoretical predictions I present in Section 3.3.3.2.

Table 3.3 – Sum of contributions and GINI index value across experimental conditions

	Average		
Measure:	MP-ROT	SP-ROT	NP-ROT
Sum of contributions	108.2	95.533	77.56
GINI index value	0.067	0.127	0.076
Spearman's ρ	0.615	0.961	0.232

3.5.3 Trend over time

One of the standard results of the public good game literature is the existence of a trend over time in contributions. Contributions tend to decrease with time. What happens in the different treatments?

Result 5 - Trend in contributions: In every treatment, I find a significant and negative trend over time in contributions. In incentivized Rank Order Tournaments, this trend is mostly due to early periods in which contributions first increase, then decrease and finally stabilise after period 5.

Support. Using Spearman correlation, I reject in every treatment the null assumption that contribution and period are independent (p-value < 0.005). Spearman ρ values are negative for all treatments ($\rho < -0.096$). I interpret this result as a significant negative trend of contributions over time. Interestingly, when looking at the pattern of contribution, presented in Figure 3.5, there seems to have a large variation of the average contribution in the earliest period. Consequently, I study Spearman correlation between contribution and period for the ten final periods (period 6 to 15). I can not reject the null assumption that the variable contribution and the variable period are independent in MP-ROT (p-value = 0.439) and in SP-ROT (p-value = 0.295) after period 5. In NP-ROT, I reject the null assumption (p-value = 0.078).

One of the consequence is that efficiency is higher in the two incentivized Rank Order Tournament treatments in the last period. When considering the fifteen and last period, contributions seem to be more important in MP-ROT and SP-ROT (around 45%) than in NP-ROT (around 20%). Using a Wilcoxon ranksum test, I reject the null assumption that groups average contributions come from the same distribution when comparing MP-ROT and NP-ROT (one-tailed test, p-value = 0.035) and when comparing SP-ROT and NP-ROT (one-tailed test, p-value = 0.051).

3.6 Discussion and conclusion

I claim in this paper that incentivized Rank Order Tournaments may align individual interest and social welfare. I provide some evidence that contributors may actually benefit from contributing in Table 3.4. In this table, I show the relationship between the rank obtained in the tournament (after that tied contribution have been ranked) and the rank of the final payoff.[19] I observe that the top contributor is more likely to be the agent with the highest payoff in the incentivized tournaments (32.86% of the cases in MP-ROT, 66.67% of the cases in SP-ROT) in comparison to NP-ROT (3.33% of the cases in NP-ROT, due to the ties). Moreover, the agent with the lowest contribution is less likely to be the richest agent in the incentivized tournaments (29.05% in MP-ROT, 17.78% in SP-ROT) with respect to NP-ROT (72.67% of the cases in NP-ROT) after that the public good has been provided.

In this paper, (i) I replicate the paper of Angelovski et al. (2017), (ii) I introduce a new Rank Order Tournament with a single prize (SP-ROT) and (iii) I compare these two treatments with a Rank Order Tournament with no prize (NP-ROT). MP-ROT leads to higher contributions than NP-ROT. SP-ROT is not more efficient than NP-ROT. One potential explanation is that SP-ROT leads to significantly higher inequalities and discourage agents to contribute. When comparing incentivized Rank Order Tournaments with their control in which the prize are randomly attributed, I find that only SP-ROT

[19] In order to have a final payoff ranking with no ties, I add a negligible bias to every payoff that certainly does not affect the ranking of unequal payoffs.

Table 3.4 – Frequency of rank obtained during the tournament and rank of earnings in a period (in%)

		Final rank obtained in the tournament											
Treatments:		MP-ROT				SP-ROT				NP-ROT			
	Rank	1	2	3	4	1	2	3	4	1	2	3	4
Rank	1	32.86	10	28.10	29.05	66.67	5.19	10.37	17.78	3.33	4.44	20	72.67
of	2	22.86	28.58	18.10	30.48	0.74	6.67	26.67	65.93	4.67	15.33	60.67	19.33
Final	3	12.86	42.86	30	14.29	9.63	20.74	53.33	16.30	16	66	12	6
Payoff	4	31.43	18.57	23.81	26.19	22.96	67.41	9.63	0	76	14.67	7.33	2

Note. The final rank obtained in the tournament corresponds to the rank of the contribution obtained after that the random process applied to the tied contributions. The rank of the final payoff is equal to the rank of the final payoff plus a insignificant noise.

outperforms its control. This result moderates the ones of Angelovski et al. (2017). When Rank Order Tournaments certainly lead to *ex post* inequalities for equal contributions *ex ante*, the mechanism is less efficient.

This article is a part of the large literature about Public Good Games and, precisely sheds light on a new enhancing-efficiency mechanism. The core idea here was to test a new mechanism that readapts the incentive scheme of the game. Outside the lab, in order to implement this kind of mechanisms, first there is a need for a central authority capable of observing the objective level of the effort provided. Second, there is a need for social acceptance of the privileged status. If these conditions are completed, then the mechanism can be easily explained and applied.

More research is needed to keep improving the state of knowledge about the effects of competition on public goods provision. It can be a solution to counter free-riding behaviours. This kind of mechanisms is more likely to be efficient in a world with agents homogeneous in endowment (among others, time and money). However, I believe that, in most situations, agents differ in endowment. It would be interesting to test this mechanism in a heterogeneous population. The first objective is to study if this mechanism is likely to lead to better contributions to the public good when agents are not endowed with the same value. The second objective is to come with a potential solution when agents are heterogeneous. A first part of the answer can be relative competition such as implemented in Dickinson and Isaac (1998).

Bibliography

Andreoni, J. (1990). Impure altruism and donations to public goods: A theory of warm-glow giving. *The Economic Journal 100*(401), 464–477.

Andreoni, J. (1995). Cooperation in public-goods experiments: kindness or confusion? *The American Economic Review*, 891–904.

Angelovski, A., T. Neugebauer, M. Servátka, et al. (2017). Can rank-order competition resolve the free-rider problem in the voluntary provision of impure public goods? experimental evidence. Technical report, Dipartimento di Economia e Finanza, LUISS Guido Carli.

Bock, O., I. Baetge, and A. Nicklisch (2014). hroot: Hamburg registration and organization online tool. *European Economic Review 71*, 117–120.

Bolton, G. E. and A. Ockenfels (2000). ERC: A theory of equity, reciprocity, and competition. *The American Economic Review 90*(1), 166–193.

Bornstein, G. and I. Erev (1994). The enhancing effect of intergroup competition on group performance. *International Journal of Conflict Management 5*(3), 271–283.

Bornstein, G. and A. Rapoport (1988). Intergroup competition for the provision of step-level public goods: Effects of preplay communication. *European Journal of Social Psychology 18*(2), 125–142.

Bornstein, G., A. Rapoport, L. Kerpel, and T. Katz (1989). Within-and between-group communication in intergroup competition for public goods. *Journal of Experimental Social Psychology 25*(5), 422–436.

Buckley, E. and R. Croson (2006). Income and wealth heterogeneity in the voluntary provision of linear public goods. *Journal of Public Economics 90*(4-5), 935–955.

Bull, C., A. Schotter, and K. Weigelt (1987). Tournaments and piece rates: An experimental study. *Journal of Political Economy 95*(1), 1–33.

Burton-Chellew, M. N., A. Ross-Gillespie, and S. A. West (2010). Cooperation in humans: competition between groups and proximate emotions. *Evolution and Human Behavior 31*(2), 104–108.

Cabrera, S., E. Fatás, J. A. Lacomba, and T. Neugebauer (2013). Splitting leagues: promotion and demotion in contribution-based regrouping experiments. *Experimental Economics 16*(3), 426–441.

Cárdenas, J. C. and C. Mantilla (2015). Between-group competition, intra-group cooperation and relative performance. *Frontiers in Behavioral Neuroscience 9*, 33.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: a selective survey of the literature. *Experimental Economics 14*(1), 47–83.

Colasante, A., A. García-Gallego, N. Georgantzis, A. Morone, and T. Temerario (2019). Intragroup competition in public good games: The role of relative performance incentives and risk attitudes. *Journal of Public Economic Theory*.

Corazzini, L., M. Faravelli, and L. Stanca (2010). A prize to give for: An experiment on public good funding mechanisms. *The Economic Journal 120*(547), 944–967.

Croson, R., E. Fatas, T. Neugebauer, and A. J. Morales (2015). Excludability: A laboratory study on forced ranking in team production. *Journal of Economic Behavior & Organization 114*, 13–26.

Croson, R. T. (2001). Feedback in voluntary contribution mechanisms: an experiment in team production. In *Research in Experimental Economics*, pp. 85–97. Emerald Group Publishing Limited.

Dawes, R. M., J. M. Orbell, R. T. Simmons, and A. J. Van De Kragt (1986). Organizing groups for collective action. *American Political Science Review 80*(4), 1171–1185.

Dechenaux, E., D. Kovenock, and R. M. Sheremeta (2015). A survey of experimental research on contests, all-pay auctions and tournaments. *Experimental Economics 18*(4), 609–669.

Dickinson, D. L. and R. M. Isaac (1998). Absolute and relative rewards for individuals in team production. *Managerial and Decision Economics*, 299–310.

Erev, I., G. Bornstein, and R. Galili (1993). Constructive intergroup competition as a solution to the free rider problem: A field experiment. *Journal of Experimental Social Psychology 29*, 463–463.

Faravelli, M. and L. Stanca (2012). Single versus multiple-prize all-pay auctions to finance public goods: An experimental analysis. *Journal of Economic Behavior & Organization 81*(2), 677–688.

Faravelli, M. and L. Stanca (2014). Economic incentives and social preferences: Causal evidence of non-separability. *Journal of Economic Behavior & Organization 108*, 273–289.

Fischbacher, U. (2007). z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics 10*(2), 171–178.

Fischbacher, U., S. Schudy, and S. Teyssier (2014). Heterogeneous reactions to heterogeneity in returns from public goods. *Social Choice and Welfare 43*(1), 195–217.

Goeree, J. K., E. Maasland, S. Onderstal, and J. L. Turner (2005). How (not) to raise money. *Journal of Political Economy 113*(4), 897–918.

Gunnthorsdottir, A. and A. Rapoport (2006). Embedding social dilemmas in intergroup competition reduces free-riding. *Organizational Behavior and Human Decision Processes 101*(2), 184–199.

Irlenbusch, B. and G. K. Ruchala (2008). Relative rewards within team-based compensation. *Labour Economics 15*(2), 141–167.

Lazear, E. P. and S. Rosen (1981). Rank-order tournaments as optimum labor contracts. *Journal of Political Economy 89*(5), 841–864.

Markussen, T., E. Reuben, and J.-R. Tyran (2014). Competition, cooperation and collective choice. *The Economic Journal 124*(574).

Morgan, J. (2000). Financing public goods by means of lotteries. *The Review of Economic Studies 67*(4), 761–784.

Morgan, J. and M. Sefton (2000). Funding public goods with lotteries: experimental evidence. *The Review of Economic Studies 67*(4), 785–810.

Niederle, M. and L. Vesterlund (2007). Do women shy away from competition? do men compete too much? *The Quarterly Journal of Economics 122*(3), 1067–1101.

Nikiforakis, N. (2010). Feedback, punishment and cooperation in public good experiments. *Games and Economic Behavior 68*(2), 689–702.

Olson, M. (1965). *Logic of collective action: Public goods and the theory of groups*. Harvard University Press.

Puurtinen, M. and T. Mappes (2009). Between-group competition and human cooperation. *Proceedings of the Royal Society of London B: Biological Sciences 276*(1655), 355–360.

Rapoport, A. and G. Bornstein (1987). Intergroup competition for the provision of binary public goods. *Psychological Review 94*(3), 291.

Rapoport, A., G. Bornstein, and I. Erev (1989). Intergroup competition for public goods: Effects of unequal resources and relative group size. *Journal of Personality and Social Psychology 56*(5), 748.

Reuben, E. and J.-R. Tyran (2010). Everyone is a winner: Promoting cooperation through all-can-win intergroup competition. *European Journal of Political Economy 26*(1), 25–35.

Sell, J. and R. K. Wilson (1991). Levels of information and contributions to public goods. *Social Forces 70*(1), 107–124.

Tan, J. H. and F. Bolle (2007). Team competition and the public goods game. *Economics Letters 96*(1), 133–139.

Théroude, V. and A. Zylbersztejn (2019). Cooperation in a risky world. *Journal of Public Economic Theory (forthcoming)*.

Weimann, J. (1994). Individual behaviour in a free riding experiment. *Journal of Public Economics 54*(2), 185–200.

A Appendix

A.1 Additional evidence

A.1.1 Result 1

In Table A.1, I run one regression comparing efficiency - through the sum of contributions - in three treatments: MP-ROT, SP-ROT and NP-ROT. I focus on the entire game, i.e. the fifteen periods. I find that the sum of contributions are significantly higher in MP-ROT than in NP-ROT (one-tailed t-test, p-value = 0.053). I do not find any differences in sum of contributions when comparing MP-ROT vs SP-ROT (two-tailed t-test, p-value = 0.375) and when comparing SP-ROT vs NP-ROT (one-tailed t-test, p-value = 0.197).

Table A.1 – Efficiency: incentivized Rank Order Tournament vs unincentivized Rank Order Tournament

Dep. variable:	Sum of contributions within a group Period 1-15
Intercept	77.56^a
	(14.364)
MP-ROT	30.64
	(18.389)
SP-ROT	15.973
	(18.341)
N	495
$Prob > F$	0.260

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level for two-tailed tests. Dependent variable is: Sum of contributions at the the public good level. In all the models, the set of explanatory variables includes a dummy for MP-ROT and for SP-ROT. Every treatment is compared to NP-ROT. Residuals are clustered at the group level (33 groups). Standard errors are computed through the leave-one-out jackknife procedure.

A.1.2 Result 2

In Table A.2, I run one regression comparing efficiency - through the sum of contributions - in three treatments: NP-ROT, MP-CTL and SP-CTL. I focus on the entire game, i.e. the fifteen periods. Using a test of Student, I do not reject the null hypothesis that the sum of contributions are significantly different in NP-ROT than in MP-CTL (two-tailed t-test,

Table A.2 – Efficiency: NP-ROT vs Control Conditions

Dep. variable:	Sum of contributions within a group Period 1-15
Intercept	77.56^{a}
	(14.341)
MP-CTL	10.64
	(17.702)
SP-CTL	-13.18
	(21.295)
N	450
Prob > *F*	0.451

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level for two-tailed tests. Dependent variable is: Sum of contributions at the the public good level. In all the models, the set of explanatory variables includes a dummy for MP-CTL and for SP-CTL. Every treatment is compared to NP-ROT. Residuals are clustered at the group level (30 groups). Standard errors are computed through the leave-one-out jackknife procedure.

p-value = 0.552). I also do not reject the null hypothesis when I compare the sum of contributions in NP-ROT and in SP-CTL (two-tailed t-test, p-value = 0.541).

A.1.3 Result 3

Table A.3 – Efficiency across treatments

Dep. variable:	Sum of contributions within a group	
Model:	M1	M2
Intercept	88.2^{a}	64.38^{a}
	(10.333)	(15.583)
MP-ROT	20	-
	(15.396)	-
SP-ROT	-	29.1533
	-	(19.317)
N	360	285
Prob > *F*	0.207	0.149

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. Dependent variable is: Sum of contributions at the the public good level. M1 includes a dummy variable for the treatment MP-ROT. M2 includes a dummy variable for the treatment SP-ROT. M1 is compared to MP-CTL. M2 is compared to SP-CTL. Residuals are clustered at the group level in M1 (24 groups) and in M2 (19 groups). Standard errors are computed through the leave-one-out jackknife procedure.

In Table A.3, I run two regressions (M1,M2). In these regressions, I study the effect of Rank Order Tournament on the sum of contributions. I compare in model M1, the sum of contributions in MP-ROT and in MP-CTL. I do not reject the null assumption of equality in sum of contributions in MP-ROT and MP-CTL (one-tailed t-test, p-value =

0.104). In model M2, I compare the sum of contributions in SP-ROT and in SP-CTL. I reject the null assumption of equality in sum of contributions in SP-ROT and SP-CTL (one-tailed t-test, p-value = 0.075). Contributions are higher in SP-ROT than in SP-CTL.

A.1.4 Result 4

I run a regression in Table A.4 to study the level of inequalities in the five treatments. Results indicate that inequalities are higher in SP-ROT (t-test, p-value = 0.014) and in SP-CTL (t-test, p-value < 0.001) than in NP-ROT. Moreover, a test of Student indicates that inequalities are higher in MP-CTL than in MP-ROT (p-value = 0.005), are higher in SP-ROT than in MP-ROT (p-value = 0.002), and are higher in SP-CTL than in MP-ROT(0.001). Inequalities are higher (weakly significant, p-value <0.077) in SP-ROT and in SP-CTL than in MP-CTL.■

Table A.4 – Inequalities across treatments

Dep. variable:	GINI Index in periods 1-15.
Intercept	0.076^{a}
	(0.011)
MP-ROT	-.009
	(.0.013)
SP-ROT	0.05^{b}
	(.020)
MP-CTL	.018
	(.013)
SP-CTL	0.076^{a}
	(.011)
N	795
Prob > F	<0.001

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level. Dependent variable is: GINI Index value at the the public good level. In all the models, the set of explanatory variables includes the type of treatment. Every treatment is compared to NP-ROT. Residuals are clustered at the group level (53 groups). Standard errors are computed through the leave-one-out jackknife procedure.

In Table A.5, I run 3 regressions (M1,...,M3). In each regression, I study the effect of the sum of contributions on GINI index depending on the treatment. I reject the null assumption that the sum of contributions increase inequalities in the treatment MP-ROT (p-value < 0.001), SP-ROT (p-value < 0.001). I can not reject the null assumption in NP-ROT (p-value = 0.755).

Table A.5 – Inequalities over efficiency

Dep. variable:	GINI index		
Model:	M1	M2	M3
Treatment:	MP-ROT	SP-ROT	NP-ROT
Intercept	.0249[a]	-.0140[b]	.0682[b]
	(.0056)	(.0066)	(.0237)
Sum of Contributions	.0004[a]	.0015[a]	.0001
	(.00005)	(.00007)	(.0002)
N	210	140	150
Prob $>$ *F*	<0.001	<0.001	0.755

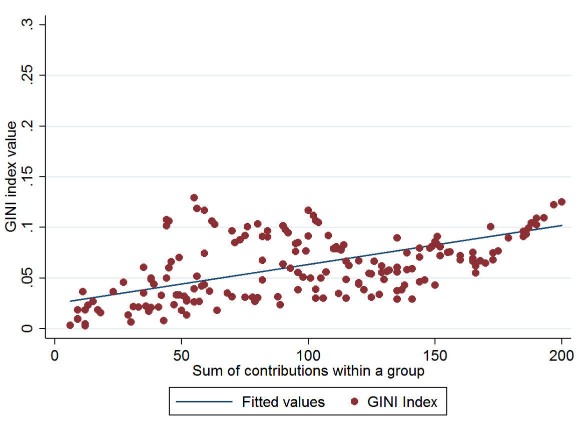
Note. *a*/*b*/*c* indicate statistical significance at the 1%/5%/10% level. Dependent variable is: Contribution to the public good (M1-M5). In all the models, the set of explanatory variables includes: Period. Residuals are clustered at the group level in M1(13 groups), M2(9 groups), M3(10 groups), M4(10 groups) and M5(10 groups). Standard errors are computed through the leave-one-out jackknife procedure.

A.1.5 Result 5

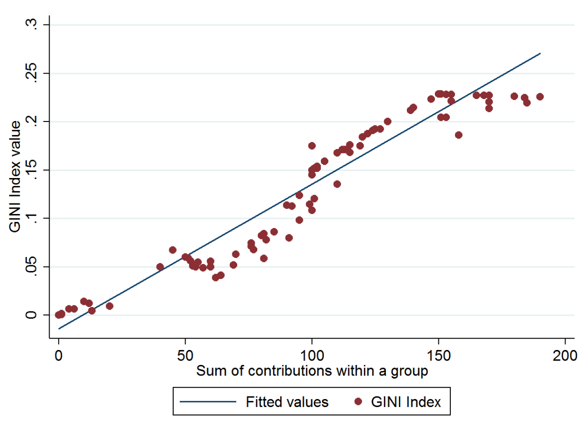
In Table A.6, I run 3 regressions (M1,. . . ,M3). In each regression, I study the effect of time (through the variable period) on contributions depending on the treatment. In the three regressions, I find a negative effect of time on contributions. M1 focuses on the effect of time in MP-ROT. In this treatment, I cannot reject the null assumption, namely, there is no effect of time on contributions (t-test, p-value = 0.105). This trend is weakly significant in SP-ROT (t-test, p-value = 0.076). In NP-ROT, the coefficient of period is significantly different from 0 (p-value = 0.026), and contributions tend to decrease over time.

Finally, in Table A.7, I find that the sums of contributions in period 15 are significantly higher in MP-ROT (one-tailed t-test, p-value = 0.019) and in SP-ROT (one-tailed t-test, p-value = 0.024) with respect to NP-ROT.

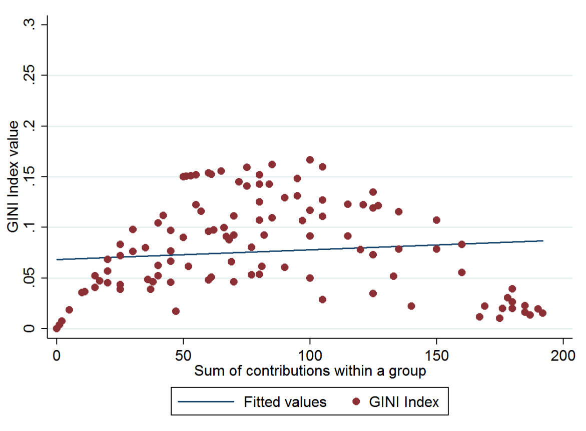
Figure A.1 – GINI Index over Sum of contributions within a group across treatments



(a) MP-ROT



(b) SP-ROT



(c) NP-ROT

Table A.6 – Trend over contributions by treatments

Dep. variable:	Contributions in periods 1-15.		
Model:	M1	M2	M3
Treatment:	MP-ROT	SP-ROT	NP-ROT
Intercept	31.485^a	28.004^a	27.546^a
	(2.796)	(2.745)	(4.725)
Period	-.571	-.578^c	-1.019^b
	(.328)	(0.283)	(.383)
N	840	560	600
Prob > *F*	0.105	0.076	0.026

Note. *a*/*b*/*c* indicate statistical significance at the 1%/5%/10% level. Dependent variable is: Contribution to the public good (M1-M3). In all the models, the set of explanatory variables includes: Period. Residuals are clustered at the group level in M1(13 groups), M2(9 groups), M3(10 groups). Standard errors are computed through the leave-one-out jackknife procedure.

Table A.7 – Efficiency: incentivized Rank Order Tournament vs unincentivized Rank Order Tournament

Dep. variable:	Sum of contributions within a group Period 15
Intercept	45[a]
	(11.397)
MP-ROT	38.286[b]
	(17.597)
SP-ROT	49.667[b]
	(24.043)
N	33
$Prob > F$	0.044

Note. $a/b/c$ indicate statistical significance at the 1%/5%/10% level for two-tailed tests. Dependent variable is: Sum of contributions at the the public good level in period 15. In all the models, the set of explanatory variables includes a dummy for MP-ROT and for SP-ROT. Every treatment is compared to NP-ROT. Residuals are clustered at the group level (33 groups). Standard errors are computed through the leave-one-out jackknife procedure.

A.2 Instructions (*Translated from French*)

A.2.1 MP-ROT

Instructions

Thank you for participating to this experiment in economics. Please turn off your phone and do not communicate with the other participants unless I ask you to. If you have any questions, you can press the red button on the left of your desk at any time, I will come to answer you in private.

During this experiment, you are going to make decisions. These decisions can make you earn money. During the whole experiment, I will not talk about Euros, but about Experimental Currency Units (ECU). Your earnings will be computed in ECU, then converted in Euros at the time of the payment. The conversion rate is the following:

10 ECU = €1,5

You earn an additional €5 for participating to this experiment. At the end of the session, you will receive your payment. You will be paid in Euros, in cash and in private in a separated room.

With who are you going to interact ?

At the beginning of the experiment, the computer program will randomly form groups of 4 people. The groups will be made of the same members during the whole experiment. The identity of group members won't be revealed at any moment.
The experiment lasts 15 identical periods

The decision
At the beginning of each period, each group member is endowed with 50ECU. Each group member can invest a part of this amount in a common group account. The amount

invested must be between 0 and 50 ECU. The sum of the amounts invested in the common group account by each group member is then multiplied by 2 and redistributed between group members according to a rule explicited below. For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

The rank

At the end of each period, a rank is attributed to each group member. Ranking is determined as follows : the lower an investment to the common group account relative to other group members investment, the higher the rank. In other words, the member who invests the higher amount ranks 1. The member who invests the lower amount ranks 4. Two different members cannot be ranked at the same position. If several group members invest the same amount, then their rank is randomly attributed. Every group member who invests the same amount has the same likelihood to be ranked at each position.

The rank obtained by each group member determines the percentage of the common account that the member will obtain:

If the amount you have invested makes you rank 1, then you will get 32,5% of the common account.

If the amount you have invested makes you rank 2, then you will get 27,5% of the common account.

If the amount you have invested makes you rank 3, then you will get 22,5%of the common account.

If the amount you have invested makes you rank 4, then you will get 17,5% of the common account.

The common group account is entirely redistributed. A period will be randomly drawn to determine your payoff for the experimental session.

How is computed your gain?

Your gain for a period is computed in the following way:

Your Gain

=

The money you have not invested

+

The sum of amounts invested by the four members in your group $\times$ 2

$\times$

Your percentage (that depends on your rank)

Where do I make my decision?

In order to make your decision, indicate the amount in the provided space and confirm your choice by clicking the OK button. Once the choice confirmed, you cannot change it anymore.

Gain simulation

On the left of your screen, you have a gain simulator. When you indicate the potential value of your investment, and the potential value of other group members investment, it computes your potential payoff.

Feedback

At the end of every period, you have available a table that informs you about the amount invested by every group members and the rank associated to each of these investments.

You are also reminded for this period:

The amount you have invested and your rank;

The sum of the amounts invested by every group members in the common account;

The total sum in the common account after multiplication;

The percentage of the common account you get;
The income you get from your personal account and the income you get from your common account;
The gain associated to this period if it is randomly drawn.

Thank you for reading again these instructions. If you have any question, please push the red button on your left or on your right side, and I will come to you individually.

A.2.2 SP-ROT

Instructions

Thank you for participating to this experiment in economics. Please turn off your phone and do not communicate with the others unless I ask you to. If you have any questions, you can press the red button on the left of your desk at any time, I will come to answer you in private.

During this experiment, you are going to make decisions. These decisions can make you earn money. During the whole experiment, I will not talk about Euros, but about Experimental Currency Units (ECU). Your earnings will be computed in ECU, then converted in Euros at the time of the payment. The conversion rate is the following:

10 ECU = €1,5

You earn an additional €5 for participating to this experiment. At the end of the session, you will receive your payment. You will be paid in Euros, in cash and in private in a separated room.

With who are you going to interact ?

At the beginning of the experiment, the computer program will randomly form groups of 4 people. The groups will be made of the same members during the whole experiment. The identity of group members won't be revealed at any moment.
The experiment lasts 15 identical periods

The decision
At the beginning of each period, each group member is endowed with 50ECU. Each group member can invest a part of this amount in a common group account. The amount invested must be between 0 and 50 ECU. The sum of the amounts invested in the common group account by each group member is then multiplied by 2 and redistributed

between group members according to a rule explicited below. For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

The rank

At the end of each period, a rank is attributed to each group member. Ranking is determined as follows : the lower an investment to the common group account relative to other group members investment, the higher the rank. In other words, the member who invests the higher amount ranks 1. The member who invests the lower amount ranks 4. Two different members cannot be ranked at the same position. If several group members invest the same amount, then their rank is randomly attributed. Every group member who invests the same amount has the same likelihood to be ranked at each position.

The rank obtained by each group member determines the percentage of the common account that the member will obtain:

If the amount you have invested makes you rank 1, then you will get 47,5% of the common account.

If the amount you have invested doesn't make you rank 1, then you will get 17,5% of the common account.

The common group account is entirely redistributed. A period will be randomly drawn to determine your payoff for the experimental session.

How is computed your gain?

Your gain for a period is computed in the following way:

$$\text{Your Gain}$$
$$=$$
$$\text{The money you have not invested}$$
$$+$$
$$\text{The sum of amounts invested by the four members in your group} \times 2$$
$$\times$$
$$\text{Your percentage (that depends on your rank)}$$

Where do I make my decision?

In order to make your decision, indicate the amount in the provided space and confirm your choice by clicking the OK button. Once the choice confirmed, you cannot change it anymore.

Gain simulation

On the left of your screen, you have a gain simulator. When you indicate the potential value of your investment, and the potential value of other group members investment, it computes your potential payoff.

Feedback

At the end of every period, you have available a table that informs you about the amount invested by every group members and the rank associated to each of these investments.

You are also reminded for this period:

The amount you have invested and your rank;

The sum of the amounts invested by every group members in the common account;

The total sum in the common account after multiplication;

The percentage of the common account you get;

The income you get from your personal account and the income you get from your common account;

The gain associated to this period if it is randomly drawn.

Thank you for reading again these instructions. If you have any question, please push the red button on your left or on your right side, and I will come to you individually.

A.2.3 NP-ROT

Instructions

Thank you for participating to this experiment in economics. Please turn off your phone and do not communicate with the other participants unless I ask you to. If you have any questions, you can press the red button on the left of your desk at any time, I will come to answer you in private.

During this experiment, you are going to make decisions. These decisions can make you earn money. During the whole experiment, I will not talk about Euros, but about Experimental Currency Units (ECU). Your earnings will be computed in ECU, then converted in Euros at the time of the payment. The conversion rate is the following:

10 ECU = €1,5

You earn an additional €5 for participating to this experiment. At the end of the session, you will receive your payment. You will be paid in Euros, in cash and in private in a separated room.

With who are you going to interact ?

At the beginning of the experiment, the computer program will randomly form groups of 4 people. The groups will be made of the same members during the whole experiment. The identity of group members won't be revealed at any moment.
The experiment lasts 15 identical periods

The decision
At the beginning of each period, each group member is endowed with 50ECU. Each group member can invest a part of this amount in a common group account. The amount invested must be between 0 and 50 ECU. The sum of the amounts invested in the common group account by each group member is then multiplied by 2 and redistributed

between group members according to a rule explicited below. For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

The rank

At the end of each period, a rank is attributed to each group member. Ranking is determined as follows : more an investment to the common group account is low relative to other group members investment, the higher the rank. In other words, the member who invest the higher amount ranks 1. The member who invest the lower amount ranks 4. Two different members can't be ranked at the same position. If several group members invest the same amount, then their rank is randomly attributed. Every group member who invests the same amount has the same likelihood to be ranked at each position.

Whatever your rank, you will get 25% of the common account.
The common group account is entirely redistributed. A period will be randomly drawn to determine your payoff for the experimental session.

How is computed your gain?

Your gain for a period is computed in the following way:

$$\text{Your Gain} \\ = \\ \text{The money you have not invested} \\ + \\ \text{The sum of amounts invested by the four members in your group} \times 2 \\ \times \\ \text{Your percentage}$$

Where do I make my decision?

In order to make your decision, indicate the amount in the provided space and confirm your choice by clicking the OK button. Once the choice confirmed, you cannot change it anymore.

Gain simulation

On the left of your screen, you have a gain simulator. When you indicate the potential value of your investment, and the potential value of other group members investment, it computes your potential payoff.

Feedback

At the end of every period, you have available a table that informs you about the amount invested by every group members and the rank associated to each of these investments. You are also reminded for this period:

The amount you have invested and your rank;

The sum of the amounts invested by every group members in the common account;

The total sum in the common account after multiplication;

The percentage of the common account you get;

The income you get from your personal account and the income you get from your common account;

The gain associated to this period if it is randomly drawn.

Thank you for reading again these instructions. If you have any question, please push the red button on your left or on your right side, and I will come to you individually.

A.2.4 MP-CTL

Instructions

Thank you for participating to this experiment in economics. Please turn off your phone and do not communicate with the other participants unless I ask you to. If you have any questions, you can press the red button on the left of your desk at any time, I will come to answer you in private.

During this experiment, you are going to make decisions. These decisions can make you earn money. During the whole experiment, I will not talk about Euros, but about Experimental Currency Units (ECU). Your earnings will be computed in ECU, then converted in Euros at the time of the payment. The conversion rate is the following:

10 ECU = €1,5

You earn an additional €5 for participating to this experiment. At the end of the session, you will receive your payment. You will be paid in Euros, in cash and in private in a separated room.

With who are you going to interact ?

At the beginning of the experiment, the computer program will randomly form groups of 4 people. The groups will be made of the same members during the whole experiment. The identity of group members won't be revealed at any moment.
The experiment lasts 15 identical periods

The decision
At the beginning of each period, each group member is endowed with 50ECU. Each group member can invest a part of this amount in a common group account. The amount invested must be between 0 and 50 ECU. The sum of the amounts invested in the common group account by each group member is then multiplied by 2 and redistributed

between group members according to a rule explicited below. For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

The rank

At the end of each period, a rank is attributed to each group member. Ranks randomly determined by the software and can take four different values: 1, 2, 3 or 4. Two different members can't be ranked at the same position.

The rank obtained by each group member determines the percentage of the common account that the member will obtain:

If you rank 1, then you will get 32,5% of the common account.
If you rank 2, then you will get 27,5% of the common account.
If you rank 3, then you will get 22,5%of the common account.
If you rank 4, then you will get 17,5% of the common account.
The common group account is entirely redistributed. A period will be randomly drawn to determine your payoff for the experimental session.

How is computed your gain?

Your gain for a period is computed in the following way:

$$\text{Your Gain}$$
$$=$$
$$\text{The money you have not invested}$$
$$+$$
$$\text{The sum of amounts invested by the four members in your group} \times 2$$
$$\times$$
$$\text{Your percentage (that depends on your rank)}$$

Where do I make my decision?

In order to make your decision, indicate the amount in the provided space and confirm your choice by clicking the OK button. Once the choice confirmed, you cannot change it anymore.

Gain simulation

On the left of your screen, you have a gain simulator. When you indicate the potential value of your investment, and the potential value of other group members investment, it computes your potential payoff.

Feedback

At the end of every period, you have available a table that informs you about the amount invested by every group members and the rank associated to each of these investments. You are also reminded for this period:

The amount you have invested and your rank;

The sum of the amounts invested by every group members in the common account;

The total sum in the common account after multiplication;

The percentage of the common account you get;

The income you get from your personal account and the income you get from your common account;

The gain associated to this period if it is randomly drawn.

Thank you for reading again these instructions. If you have any question, please push the red button on your left or on your right side, and I will come to you individually.

A.2.5 SP-CTL

Instructions

Thank you for participating to this experiment in economics. Please turn off your phone and do not communicate with the other participants unless I ask you to. If you have any questions, you can press the red button on the left of your desk at any time, I will come to answer you in private.

During this experiment, you are going to make decisions. These decisions can make you earn money. During the whole experiment, I will not talk about Euros, but about Experimental Currency Units (ECU). Your earnings will be computed in ECU, then converted in Euros at the time of the payment. The conversion rate is the following:

10 ECU = €1,5

You earn an additional €5 for participating to this experiment. At the end of the session, you will receive your payment. You will be paid in Euros, in cash and in private in a separated room.

With who are you going to interact ?

At the beginning of the experiment, the computer program will randomly form groups of 4 people. The groups will be made of the same members during the whole experiment. The identity of group members won't be revealed at any moment.
The experiment lasts 15 identical periods

The decision

At the beginning of each period, each group member is endowed with 50ECU. Each group member can invest a part of this amount in a common group account. The amount invested must be between 0 and 50 ECU. The sum of the amounts invested in the common group account by each group member is then multiplied by 2 and redistributed

between group members according to a rule explicited below. For all the group members, the amount that is not invested in the common project is stored on a personal account. Thus, if a group member stores X ECU on his/her personal account, he/she will recover exactly X ECU.

The rank

At the end of each period, a rank is attributed to each group member. Ranks randomly determined by the software and can take four different values: 1, 2, 3 or 4. Two different members can't be ranked at the same position.

The rank obtained by each group member determines the percentage of the common account that the member will obtain:

If you rank 1, then you will get 32,5% of the common account.
If you don't rank 1, then you will get 17,5% of the common account.

The common group account is entirely redistributed. A period will be randomly drawn to determine your payoff for the experimental session.

How is computed your gain?

Your gain for a period is computed in the following way:

$$\begin{gathered}\text{Your Gain}\\=\\\text{The money you have not invested}\\+\\\text{The sum of amounts invested by the four members in your group} \times 2\\\times\\\text{Your percentage (that depends on your rank)}\end{gathered}$$

Where do I make my decision?

In order to make your decision, indicate the amount in the provided space and confirm your choice by clicking the OK button. Once the choice confirmed, you cannot change it anymore.

Gain simulation

On the left of your screen, you have a gain simulator. When you indicate the potential value of your investment, and the potential value of other group members investment, it computes your potential payoff.

Feedback

At the end of every period, you have available a table that informs you about the amount invested by every group members and the rank associated to each of these investments.

You are also reminded for this period:

The amount you have invested and your rank;

The sum of the amounts invested by every group members in the common account;

The total sum in the common account after multiplication;

The percentage of the common account you get;

The income you get from your personal account and the income you get from your common account;

The gain associated to this period if it is randomly drawn.

Thank you for reading again these instructions. If you have any question, please push the red button on your left or on your right side, and I will come to you individually.

General Conclusion

Understanding cooperation is one of the challenge of social sciences. In order to enrich knowledge about cooperation, experimental economists have used the Public Good Game for almost four decades. In this thesis, I have given new insights on how people cooperate in a more complex environment - in which agents may differ in endowment, in MPCR, or in which MPCR is uncertain.

In Chapter 1, I have investigated the literature which relaxes the standard assumption of homogeneity in endowment and homogeneity in return of the public good (MPCR) within a group. My general conclusion is that, despite a normative conflict exacerbated, heterogeneity does not harm cooperation. Yet, there is still a substantial underprovision of public goods. As underprovision leads to a social loss in welfare, I have investigated whether heterogeneous agents manage to overcome the underprovision problem with efficiency-enhancing mechanisms. The results are mixed. On one hand, agents heterogeneous in endowment manage to increase efficiency when mechanisms are available. On the other hand, agents heterogeneous in MPCR do not totally overcome the underprovision problem. The main reason for this result is that efficiency is associated with inequalities in payoffs that are not accepted by the agents left behind.

These results suggest that heterogeneous agents are ready to cooperate even when they do not share the same view about what level of contributions they should adopt. In a large majority of the surveyed studies, authors do not observe statistical differences in the level of contribution dedicated to the public good with respect to homogeneous groups. Methodologically, a further step would be to run a meta-analysis of these articles to quantify the effect of heterogeneity (depending on its type) when no mechanisms are implemented to promote cooperation.

Chapter 1 somehow complements the empirical studies investigating the effect on heterogeneity in public goods provision (Alesina et al., 1999; Alesina and La Ferrara, 2000; Miguel, 2004; Miguel and Gugerty, 2005; Algan et al., 2016). These papers find a negative effect of ethnic diversity on contributions to the public good. Chapter 1 gives some evidence that the negative effect of heterogeneity observed outside the laboratory should not come neither from differences in return from public goods nor from differences in income. Of course, the effect of income and return could be additive. To the best of my knowledge this question has not been investigated in the laboratory.

Additionally, there is a need for future research on the effect of heterogeneity. Returns of the public good outside the laboratory are often time-dependant. Young agents benefit more from the educational system while older agents benefit more from the heath system. It would be interesting to study inter-generational solidarity in the laboratory in which agents know for sure that the left behind (low MPCR) in period 1 would be the privileged agents (high MPCR) in period 2 and *vice versa*. Finally, economists have to keep investigating on the mechanisms that would achieve efficiency when agents are heterogeneous in return from the public good.

In Chapter 2, co-written with Adam Zylbersztejn, we study the effects of environmental risk on cooperation. We call an environmental risk a situation in which the return of the public good is a lottery at the the time of the decision. We consider two kinds of risk. In the first risky treatment, the risk is collective: once every agent makes her decision, every agent gets the same MPCR. In the second risky treatment, the risk is individual: once every agent makes her decision, every agent learns her individual MPCR. We compare these two risky treatments with a standard situation in which the MPCR is certain, homogeneous, and known by advance. We find that uncertainty does not affect neither other-regarding preferences (measured with conditional contributions), nor beliefs about other group members average contribution, nor contributions.

With this chapter, we show that environmental risk does not hamper cooperation. Despite risk aversion, subjects keep contributing to the public good. This chapter highlights the complex link between risk preferences and other-regarding preferences. Agents contribute to the public good as much when the return of the public is risky or when it is certain. There is a need for more research on how risk preferences and other-regarding preferences interact. The link between risk-preferences and other-regarding preferences is still unclear and, no theory reaches the consensus.
Additionally, in this chapter, we observe an underprovision of the public good. As far as I know, no mechanisms have been tested in a risky context. Yet, the improvement of efficiency due to a mechanism in a risky context is uncertain, especially because an individual risk may lead to inequalities in *ex post* payoffs. Another way to work on risky returns is to start from a situation with no environmental risk in which agents cooperate and to incorporate risk. This situation is likely to exacerbate the normative conflict and to erode coordination.
Taking together, Chapter 1 and Chapter 2 indicate that the standard experimental methodology provides a robust and conservative measure of human cooperation. Relaxing the standard hypotheses of homogeneity and certainty does not change the pattern of cooperation observed in the classic game.

Chapter 3 is slightly different. In this chapter, I investigate the effects of *within-group* competition in Public Good Games. Agents compete for a higher Marginal Per Capita Return (MPCR) from the public good. The rank in the competition - and therefore the MPCR - depends on how one's contribution ranks within the group. I implement two kinds of incentivized tournament. In the *Multiple-Prize Rank Order Tournament* treatment (MP-ROT), four subjects compete for four different MPCRs. In the *Single-Prize Rank Order Tournament* treatment (SP-ROT), only the best contributor gets a high MPCR. I compare these two treatments with a control condition in which agents are ranked depending on their relative contributions but such as there are no monetary rewards (NP-ROT). My research hypothesis is that incentivized tournaments increase contributions to the public good. I find mixed evidence about the efficiency of incentivized Rank Order

Tournaments: only MP-ROT outperforms the NP-ROT. Additionally, I compare MP-ROT and SP-ROT with two controls in which the same MPCRs are randomly attributed. I find that only SP-ROT outperforms its control in which the prize is randomly attributed. The standard way to provide public goods lies on cooperation. Yet, this chapter gives some evidence that competition can foster the private provision of public goods. Both ways to provide public goods are antagonistic. It would be interesting to develop an experiment to study the individual choice of contribution in both contexts depending on subjects' elicited risk preferences and on their elicited other-regarding preferences. It is likely (i) that some subjects that do contribute to the public good for other-regarding motives stop contributing when competition is implemented, and that (ii) some free-riders that do not contribute to the public good when the standard way is implemented, do contribute when there is competition.
Other important questions about competition deserve some attention. If competition increases efficiency, do agents agree to compete? Are they willing to pay to implement competition? If agents agree to enter the competition, they know that they are matched with other agents that want to compete and therefore, they may have higher beliefs about other group members contribution. The mechanism could be even more efficient in this case. In the same vein, competition may depend on the number of agents who compete. Is the mechanism efficient with a higher number of agents? On one hand, the potential gain is higher. On the other hand, it is less likely to earn the highest prizes.
Finally, competition is potentially efficient when are agents are homogeneous in endowment. What happens when agents are heterogeneous in endowment? Do agents with a low endowment contribute? In this case, is the public good as provided as when there is no competition? Can economists find a way to implement competition within a heterogeneous population?

This thesis has highlighted that there is still a lot of topics to investigate in cooperation. The public good game seems to be a good instrument to measure human cooperation behaviour. Research on this topic is even more important given the ecological and political situation of today's world. The United Nations Organization has implemented a program composed of 17 goals to transform the world. Among these 17 goals, the ecological issue (related to Goal 13, 14 and 15) and the peace issue (related to Goal 16) are central.[20] The United Nations Organization encourages countries and citizen to cooperate to change people's behaviour. It promotes the implementation of concrete mechanisms (e.g.goals 14.4; 14.6; 13.B) but also a better education/information to change behaviours (e.g. goals 13.3; 16.10).

[20]See more in https://www.un.org/sustainabledevelopment/

Bibliography

Alesina, A., R. Baqir, and W. Easterly (1999). Public goods and ethnic divisions. *The Quarterly Journal of Economics 114*(4), 1243–1284.

Alesina, A. and E. La Ferrara (2000). Participation in heterogeneous communities. *The Quarterly Journal of Economics 115*(3), 847–904.

Algan, Y., C. Hémet, and D. D. Laitin (2016). The social effects of ethnic diversity at the local level: A natural experiment with exogenous residential allocation. *Journal of Political Economy 124*(3), 696–733.

Miguel, E. (2004). Tribe or nation? nation building and public goods in Kenya versus Tanzania. *World Politics 56*(3), 327–362.

Miguel, E. and M. K. Gugerty (2005). Ethnic diversity, social sanctions, and public goods in Kenya. *Journal of Public Economics 89*(11-12), 2325–2368.

RULES AND EFFICIENCY IN COLLECTIVE CHOICES: AN EXPERIMENTAL APPROACH

Vincent Théroude

Abstract

This thesis contains three essays on cooperation, observed through the contributions in the Public Good Game.
In the first chapter, I survey the literature on heterogeneity in linear Public Good Games. I distinguish two kinds of heterogeneity: heterogeneity in endowment and heterogeneity in return from the public good (i.e. MPCR). Despite a normative conflict exacerbated, heterogeneous agents contribute as much as homogeneous agents to the public good. Are they able to use mechanisms to reach efficiency (i.e. a full provision of the public good)? I find mixed evidence. Agents heterogeneous in endowment are able to govern themselves and to reach efficiency while agents heterogeneous in MPCR do not perfectly overcome the underprovision problem.
In the second chapter, co-written with Adam Zylbersztejn, we investigate the effects of environmental risk on cooperation. We call an environmental risk a situation in which the return of the public good is risky at the time of the decision. We consider, in our experiment, two kinds of risk: an individual one (i.e. the MPCR is determined independently for each group member) and a collective one (i.e. the MPCR is the same for each group member). We find that risk does not affect cooperation: subjects do not contribute to the public good differently when the MPCR is certain or when it is risky.
In the third chapter, I investigate the effects of a mechanism based on within-group competition to provide public goods. In my experimental treatments, agents compete for a higher MPCR from the public good. The rank in the competition - and therefore the MPCR - depends on how one's contribution ranks within the group. I find that competition improves public goods provision only when it does not generate too large inequalities.

Keywords: Public good game; Heterogeneity; Risk; Other-regarding preferences ; Experimental Economics

Résumé

Cette thèse contient trois essais sur la coopération, mesurée à travers les contributions dans le jeu du bien public.
Dans le premier chapitre, je propose une revue de la littérature sur l'hétérogénéité dans les jeux de bien public linéaires. Je distingue deux types d'hétérogénéité : l'hétérogénéité en dotation et l'hétérogénéité en rendement du bien public (c'est-à-dire en MPCR). Malgré un conflit normatif exacerbé, les agents hétérogènes contribuent autant au bien public que des agents homogènes. Sont-ils en mesure d'utiliser des mécanismes pour atteindre l'efficience (une provision complète du bien public) ? Mes résultats sont nuancés. Les agents hétérogènes en dotation sont capables de "s'autogouverner" et d'atteindre l'efficience tandis que les agents hétérogènes en MPCR ne parviennent pas parfaitement à surmonter le problème de la sous-provision du bien public.
Dans le deuxième chapitre, co-écrit avec Adam Zylbersztejn, nous étudions les effets d'un risque environnemental sur la coopération. Nous appelons risque environnemental une situation dans laquelle le rendement du bien public est risqué au moment de la décision. Nous considérons, dans notre expérience, deux types de risque : un risque individuel (le MPCR est déterminé indépendamment pour chaque membre du groupe) et un risque collectif (le MPCR est le même pour chaque membre du groupe). Nous constatons que le risque n'affecte pas la coopération : les sujets ne contribuent pas différemment au bien public lorsque le MPCR est certain ou lorsqu'il est risqué.
Dans le troisième chapitre, j'examine les effets d'un mécanisme fondé sur la compétition intragroupe pour financer des biens publics. Dans mon expérience, les agents sont en compétition pour obtenir un MPCR plus élevé. Le rang dans la compétition - et donc le MPCR - dépend de la façon dont la contribution d'une personne se classe au sein de son groupe. Je trouve que la compétition n'améliore la provision des biens publics que lorsqu'elle ne génère pas d'inégalités trop importantes.

Mots Clés : Jeu de bien public ; Hétérogénéité ; Risque ; Préférences Sociales ; Economie Expérimentale